

SUGAR CANE EXPERIMENTAL STATION
OF THE
SUGAR GROWERS' ASSOCIATION.
J. T. CRAWLEY, Director.

BULLETIN No. 1.

Organization of the Station and
Cultivation of Sugar Cane in Porto Rico

BY

J. T. CRAWLEY, Director.

CANE INSECTS

BY

D. L. VAN DINE, Entomologist.

CANE DISEASES

BY

J. R. JOHNSON, Pathologist.

SAN JUAN, P. R.
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SUGAR CANE EXPERIMENTAL STATION.

STATION STAFF.

J. T. Crawley.—Director.

D. L. VAN DINE.—Entomologist.

J. R. JOHNSON.—Pathologist.

DR. FRITZ.—Chemist.

J. H. SOUGHER.—Superintendent.

FIRST REPORT
OF
DIRECTOR EXPERIMENTAL ESTATION

BULLETIN OF EXPERIMENTAL STATION

FIRST REPORT OF THE DIRECTOR OF THE EXPERIMENT STATION.

This report covers the time intervening between the 10th of August, 1910, and May 1st, 1911.

1. STATION SITE.

In my report to the directors of this Association in May of last year, discussing the advisability of establishing an experiment station for the study of various phases of the sugar industry, I recommended that land be purchased to the west of the Military Road, between Río Piedras and Central Vannina, the low land to be used for experimental purposes, and the high land for locating houses, laboratories, etc. It appears that but a small part of the level land only could be secured, and therefore the directors purchased the hill land to the south of the Military Road.

The chief experimental plots are being located in the low land, and the hills will be utilized as building sites for dwellings, laboratories, etc., for the propagation of varieties of cane, for certain experiments in soil improvement, and for pasturage.

2. STATION STAFF.

All of the positions recommended in my original report have been filled, as follows:

(1) *Entomologist*.—D. L. Van Dine. Mr. Van Dine is a graduate of Cornell University, and was for several years entomologist to the United States Experiment Station in Hawaii, and more recently was with the United States Department of Agriculture, Bureau of Entomology, having charge of sugar cane and rice insect investigations in the South, in cooperation with the Louisiana Sugar Experiment Station at Audubon Park.

(2) *Pathologist*.—John R. Johnston. He is a graduate of Harvard University and came here from the United States Department of Agriculture, Pathological Laboratory of the Bureau of Plant Industry, and has had several years' experience in the West Indies, having for a number of years been engaged in a study of the disease affecting the cocoanut palms.

(3) *Chemist*.—Fritz Zerban, Ph. D. Dr. Zerban is a graduate of the University of Munich, and was instructor in chemistry in that university, also in the Royal Institute of Agriculture, Berlin; afterwards research chemist in the College of the City of New York and the University of North Carolina. More recently he was successively research chemist at the Louisiana Sugar Experiment Station, Audubon Park, New Orleans, La., director of the Sugar Experiment Station, Lima, Peru, and sub-director of the Agricultural Experiment Station, Tucuman, Argentine.

(4) *Station Superintendent*.—T. H. Lougher. Mr. Lougher was for a number of years assistant at the experiment station of the Hawaiian Sugar Planters' Association, Honolulu, Hawaii, and later took a special course in the Audubon Sugar School of the Louisiana State University.

3. GENERAL PREPARATION.

The preliminary work of preparation consisted in the erection of a cottage, a combined stable and carriage house, a house for fertilizer, tools, etc., and a house

for the mayordomo. The cottage referred to was used as a combined office and residence, but as the work increased and the letting of the contract for Station buildings was delayed a house in Río Piedras was rented and is now used as office, workroom for the entomologist and pathologist, and as a residence for some of the members of the staff.

All of the fences were in bad condition and they have either been repaired or rebuilt, and two new line fences have been built.

The land to be used for the experiments have been divided by roads and ditches into acre plots, and then, in turn, in tenth-acre plots. Approximately seven acres of hill land has been prepared, the more suitable parts having previously been surveyed and divided into one-fifth acre plots.

4. EXPERIMENTS AND PLANTINGS.

The following experimental work has been started, the plantings in most cases having already been made:

(1) *Fertilizer and lime.*—Four acres have been planted and fertilized in order to determine the requirements of these soils, both hill and valley land, and also the value of lime.

(2) *Distance planting.*—These experiments are intended to show what is the proper distance between rows and the amount of seed per acre that should be used. The distance between rows varies from six feet to four and one-half, and from five feet between hills of cane to two double rows of cane placed end to end.

(3) *A comparison of the hole and furrow system of planting, or, as they are generally called, the Porto Rican and the Hawaiian system.*—Two one-half acre plots have been planted, one in holes and in squares, the system most common in Porto Rico, and the other in furrows, or "chorro" system.

(4) *Green manuring, use of filter press cake, etc.* Suitable plots are prepared both in the hills and in the low land for the growing of cow peas and velvet beans, in order to determine the practicability of using them as green manures. Filter press cake from Central Vannina is also being tested, particularly on the poor hill land.

(5) *Varieties of cane.*—The chief planting of the experimental plots have been made with cristalina cane sent by the Central Aguirre Co., and a special experiment is designed to show the relative value of cristalina and rayada canes, which appear to be the two best canes grown in any considerable quantity in Porto Rico. Practically all of the foreign varieties, including seedlings, now found in Porto Rico have been secured and planted. These varieties were secured chiefly from Harold I. Sewall, of Naguabo, and from Guánica Centrale. The better varieties have been planted both in the hill and valley lands and in comparatively large plots, so that seed can be secured from these either for distribution or for large plantings at this Station and at the various substations.

5. SUBSTATIONS.

I have found a spirit of hearty cooperation on the part of the planters, many of whom have desired to establish substations on their own properties. The Association authorized the establishment of these under the supervision of this Station. It is intended, however, that the plantations themselves should be responsible in a large measure for these, and for this reason sites have been chosen where, in most cases, there is someone on the plantation staff willing and capable of carrying out experimental work. It is anticipated that not only will these substations yield results of direct importance to the plantations, but they will assist in the training of men in making accurate plantation tests and in the best methods of fertilizing, cultivation, etc. If carried out properly they will enable the Central Station to test principles and practice in situations where the conditions are very different from those at Río Piedras, and thus enlarge the scope and usefulness of its work.

The following substations have been established or are in process of establishment:

(1) Plazuela Sugar Co., Barceloneta, 6 acres; the principal experiments being fertilizers, lime, cane varieties, methods of planting.

(2) Guánica Central, one at Hormigueros of 9 acres and one at Sta. Emilia; devoted chiefly to fertilizers, liming and distance planting.

(3) Central Aguirre Co., at Central Florida, 10 acres; devoted to fertilizer tests and distance planting.

(4) Central Fajardo, Fajardo, 9 acres; devoted to fertilizers, liming, cultivation and planting tests, and cane varieties.

6. INSPECTION OF PLANTATIONS.

A large part of the work of the director, entomologist and pathologist has consisted of the making of visits of inspection to certain plantations, in order to study the cultivation, local conditions and the insect enemies and plant diseases that affect the cane. Visits have thus been made by some or all of us to the following plantations: Buena Vista, San Cristóbal Sugar Co., Plazuela Sugar Co., Fajardo Sugar Co., Central Carmen, Guánica Centrale, Central Aguirre, Borinquen Sugar Co., Loíza Sugar Co., Yabucoa Sugar Co. In most cases reports have been made directly to the companies interested.

Besides these reports made to the plantations we submit to this meeting general reports of the director, entomologist and pathologist, covering on the whole the conditions found, and recommendations of a general character.

7. WORK UNDER THE QUARANTINE LAW.

At the special session of August, 1910, the legislature passed an act to prevent the introduction into Porto Rico of plant diseases and insect pests, and for other purposes, and appropriated therefor the sum of \$2,000. Seeing that no steps had been taken toward the enforcement of this law, a law that was framed for the benefit of the general agricultural interests of Porto Rico, and recognizing the inadequacy of the appropriation the United States Experiment Station and this Station offered their services to the Government for the purpose of enforcing the act, until such time as more adequate appropriation could be secured. As a result Mr. W. V. Tower, of the United States Experiment Station, and D. L. Van Dine, of this Station, were commissioned inspectors and given general charge of the quarantine work. Plans for fumigation rooms, to be located at San Juan, Mayagüez, and Ponce, have been drawn and adequate equipment of the same has been ordered from abroad.

The legislature whose session has just closed passed a law to provide for the development and protection of agriculture and for the creation of a Board of Agriculture, and making an appropriation therefor of \$20,000. It will be the duty of the board to enforce the quarantine law, so that the stations will soon be relieved of this work.

It is hoped, also, that the appropriation carried by the bill will enable the board to begin successfully the introduction of beneficial birds and parasites for checking harmful insects already found here, thus assisting the work already begun by this Station.

8. BUILDINGS AND EQUIPMENT.

Contracts have been let for the erection of the office and laboratories and three residences, and these are under way. Partial equipment for the entomological and pathological laboratories has already been purchased, and the equipment for the chemical laboratory has been ordered. In addition we have built a small house to be used by the entomologist for the breeding and studying of insects.

Mr. May, special agent in charge of the United States Experiment Station, kindly put his chemical laboratory at our disposal, and Doctor Zerbán has already begun his work there, and will remain there until our laboratories have been completed.

Following are the chief lines of work which the Station will be engaged in during the coming year:

(1) Continuation of inspection of plantations.

(2) Continuation of all experimental work begun at Río Piedras and at the various substations.

(3) Investigation of Poyal and alkali lands and water of irrigation.

(4) The growing and propagation of seedlings will be undertaken in the fall.

SUGAR-CANE CULTIVATION IN PORTO RICO.

To the President and Members of the Sugar Producers' Association of Porto Rico:

In this preliminary report, I shall describe briefly the various methods of cultivation, fertilization, etc., which are in use in Porto Rico, and make such observations, recommendations, etc., as may under the circumstances seem desirable. I have already had abundant opportunity to observe all the different agricultural operations in my visits of inspection to plantations in various parts of the island.

1. SOILS.

Almost all of the soils now used for cane growing are sedimentary; the plantations are found mostly along the coast and in the opening of valleys forming the various watersheds. On the east coast and as far as San Juan on the north these soils, as a rule are stiff clays, comparatively thin, though there are notable exceptions to this, and difficult to cultivate. They become deeper and richer to the west of San Juan and have the added advantage in cases of being of limestone formation.

On the south coast soils of all classes are found, but as a rule they are deep, rich, and in many cases of limestone formation. Most of these soils, while evidently of great productivity originally, have been impoverished by a destructive system of cultivation—a system which with shallow plowing, continuous cropping without fertilization, has so impoverished the soil in many places as to render it unproductive.

Compared with Hawaii the soils are not naturally so fertile. The soils of Hawaii are derived in most cases from basaltic lava, are fresh, and of great natural productivity. Nor are they as fresh and rich as the Cuban soils, which in many cases are of limestone origin. The large amount of lime in the Cuban soils, coupled with the fact that the cane trash is not burned but incorporated with the soil, enables the Cuban planter to ratoon cane much longer than is possible in Porto Rico.

2. PREPARATION OF LAND, CULTIVATION, ETC.

As a rule the land is well prepared for planting, except in cases where this is done hurriedly in the spring in order to plant at once. Usually, however, plowing is too shallow. In most places on the south coast and in the deep soils from Bayamón to Arecibo, as well as in many other places where the surface soil is deep, the land would be greatly improved by deep steam plowing, and even where soils are shallow, they could be deepened by turning up each year a little of the subsoil. Sugar cane is an exhaustive crop, and it can be readily seen that continuous cropping of the upper six inches of soil will in time exhaust it both of its organic matter and of its plant food. Deeper plowing will not only enable the cane roots to develop better, but in many cases will bring up a fresher and richer soil to the surface.

There are two distinct systems of planting:

(1) *The hole method.*—From all accounts the Porto Rican system of planting in holes placed in squares has been followed for a long time, and is somewhat like that followed in Cuba where new land is planted. In Cuba, however, the planting is usually done more or less on the surface, without special preparation, where as in Porto Rico the cane is planted in holes after the land has been elaborately prepared for its drainage. The probable reason for the development of these two different methods in countries so nearly related as are Cuba and Porto Rico is that in the former natural drainage is excellent, owing in a measure to the limestone formation, whereas in this country most soils have a clay subsoil impervious to water and therefore have to be drained artificially.

As a rule the land is thrown into banks 11 to 14 feet wide, on which banks the cane is planted in holes in squares 5 to 7 feet apart. The small ditches between the banks serve as drainage ditches and empty into the large drainage ditches which traverse the fields at convenient distances.

In a few cases where the under drainage is good the soil is not thrown up in banks, the cane being planted as before in holes 5 to 7 feet square.

The tendency seems now to closer planting—the distance between the rows is lessened, as is also the distance between the hills of cane.

(2) *Furrow, or Hawaiian system of planting.*—In this system, which is gaining in favor, the soil is prepared level, and deep furrows are then run 5 to 6 feet apart, in which the cane is planted, the seed being laid end to end, or at intervals of a few inches apart.

This system is a necessity in irrigated lands, as the furrows serve as holders of water when irrigating. It is therefore largely used on the south coast. It is, however, adopted to planting on unirrigated plantations, as well, and is even being used to advantage on the east coast where the rain-fall is heavy. It must be noted that the drainage in the furrow system is as important as in the old Porto Rican system. The furrows in which the cane is planted act as carriers of water and empty into small drainage ditches traversing the fields at right angles to the rows. These in turn empty into the main, or larger drainage ditches.

In the past the hole system was better adapted to Porto Rico conditions than at present. When the land was fresh it could be cropped for a long time without replanting. By planting in deep holes the farmer could each year bring a lot of fresh soil around the cane which caused it to grow well and stool vigorously.

Cultivation was impossible except hand cultivation, owing to the high banks thrown up and the deep holes in which the cane was planted. Here again conditions favored the system, for labor was both cheap and plentiful, and cane allowed to ratoon for a number of years.

At the present time labor is getting more expensive, and with the stimulus of good prices for sugar the industry is expanding. This will augment the labor difficulties, and it therefore becomes necessary to discard hand labor, wherever that be possible, and substitute mechanical labor. This can be accomplished only by planting in such a way that the cane can be cultivated with plows drawn by mules or oxen.

Again land has become expensive and rents are high, and this calls for *large annual crops*.

Large annual crops can only be secured by frequent replanting, and not by ratooning for long numbers of years as at present. This is a strong argument in favor of planting in furrows where possible and cultivating between the furrows.

In all sections subject to drought and where irrigation is not practiced, good cultivation will conserve the moisture in the soil, and thus droughts will not be so severe. In hilly and sandy, land also in the low lands that can be easily drained the furrow planting and mechanical cultivation can be introduced to advantage.

As a rule it seems to me that cane is planted too wide apart—either the rows are too wide, or the holes too far apart.

It is desirable that the cane shade the ground as soon as possible as this tends to keep the ground more moist and keeps down weeds and grass, thus lessening the cost of cultivation.

Where cane is planted far apart it takes too long for it to stool out sufficiently to cover the ground, and thus valuable time is lost. This is particularly the case when the planting is done in the spring and where therefore the cane has a short time in which to mature. This becomes an important consideration where the land is poor, and where the cane is re-planted each year, or, at best, but one ratoon crop is grown.

3. VARIETIES OF CANE.

The three chief varieties planted at the present time are the Otahiti, striped and cristalina. The white was formerly the principal cane planted not only in Porto Rico and Cuba, but in the adjacent islands. But it has succumbed in the British West Indies to diseases, principally root diseases and other adverse circumstances, and has been superseded chiefly by hardier seedlings, and in Cuba by the cristalina, except in the eastern part of the island where the sugar lands are newer and richer. What has happened in those islands is happening in Porto Rico. The root disease is affecting the cane very badly, and it ratoons poorly, particularly in the older and poorer lands. But the cristalina and striped are hardier canes, ratoon better, but even they are affected by roots diseases. I consider that the introducing of hardier canes to be of the greatest necessity in Porto Rico, and the duty of each plantation to carry on experiments with varieties, so as to get canes suited to the conditions.

As a rule when several varieties are grown on the same plantation, they are grown together. Under the circumstances it is impossible to tell which are the best

canes for a given locality. It may be that in some cases some of the varieties grown are positively injurious, owing to their low sucrose and purity, since when they are milled the poor juices lower the purity of the good juices. It is very advisable that the varieties be grown and analyzed separately that their value may be accurately known.

4. FERTILIZATION.

This is a subject about which there is little known in Porto Rico. That it is getting to be of considerable importance can be seen from the following statistics of importations:

Importation of Fertilizers.

Year.	Tons.	Value.
1904.....	2,034	\$97,277
1905.....	9,455	290,653
1906.....	7,891	380,468
1907.....	14,073	309,899
1908.....	5,769	246,651
1909.....	11,670	583,421

As the lands become impoverished the greater becomes the necessity to use fertilizers. As the station is making extensive experiments with fertilizers, not only at Río Piedras, but in different parts of the island a detailed discussion of this subject will be left for the future, when more data will be available.

On the south side of the island tankage is the favorite fertilizer, while in other parts soluble chemical fertilizers are generally used. The average application is probably 400 pounds to the acre, often applied in two doses.

Tankage is an insoluble compound and should be applied in the furrows before planting. Soluble chemical fertilizers can be applied either before planting, or after the cane has germinated. There is a tendency to apply fertilizers in holes about the stalks of cane—they being made with an iron bar or a hoe. A better way would be to scatter the dose broadcast about the roots of the cane, where the cane has been planted in holes, or scatter it continuously in the furrow where the cane has been planted in furrows. This is more necessary in case of insoluble fertilizers like tankage than with soluble chemical fertilizers. In the latter case the plant food is carried down and divided up by the moisture of the soil, and rains, but insoluble fertilizers should be placed where the roots of the cane can reach them.

It is recommended that plantations make experiments with soluble nitrogen compounds, either nitrate of soda or sulphate or ammonia. After a series of experiments covering many years the Hawaiian Station has found that nitrogen is the most necessary element to apply to cane in those islands, and the nitrogen as a rule is supplied in the form of sulphate of ammonia in mixed fertilizers, and as nitrate of soda when applied as a top dressing. In the British Islands the same thing has been found true, but the nitrogen is supplied usually in the form of sulphate of ammonia. As yet I know of no conclusive experiments that have been made to determine what element or elements the Porto Rican soils stand most in need of.

At present only general recommendation can be made—recommendations based on results obtained in other countries.

Insoluble fertilizers should be applied in the furrow before planting.

Soluble fertilizers should be applied in two doses where this is practicable and in all cases the fertilizers should be well scattered and not applied in heaps.

Where cane is backward and yellow, either a soluble chemical compound containing a large quantity of nitrogen, or nitrate of soda or sulphate of ammonia should be applied.

5. INSECT PESTS AND DISEASES OF CANE.

These subjects are discussed as fully as the circumstances permit by the entomologist and pathologist.

You will see that Mr. Van Dine reports the moth borer, to be the most harmful insect found, and he gives practical methods of alleviating the situation. It is our opinion, however, that the root diseases are doing quite as much damage as the insect pests.

The root disease is found to every plantation and practically in every field that we have examined, and does not seem to have received in the past the attention that it deserves.

Practically the only known remedies are the plowing up and exposing to the sun the diseased roots, frequent replanting, fertilizing and good cultivation. As a rule those plantations that give the best attentions to their fields have the least amount of root disease, and those plantations or fields where this is neglected suffer the most.

6. SEED SELECTION.

Attention is called by both the entomologist and pathologist to the fact that too little care is exercised in the selection and preparation of seed for planting. Particular attention is called to this subject. Repeated examination has shown that the poor conditions of new fields was the result of planting seed suffering from root disease; and it is the custom almost every where to make the selection of seed in the field where the seed are to be planted. The diseased and borer infested canes are discarded without being destroyed, and act as centers of infection for the newly-planted field.

7. GREEN MANURING.

One of the chief reasons why the sugar-cane soils of Porto Rico have become impoverished is because of the gradual destruction of the organic matter by continuous cultivation. In many places the soil is not allowed to rest, but is cropped from year to year—as soon as one crop has been harvested the fields are cleared for another. In the consequent turning over of the soil, aerating and exposing it to the sun, coupled with comparatively clean cultivation, the organic matter is burned out. Now organic matter is of the greatest necessity in cultivated soils. In the first place it makes the soil light in character, easy to cultivate, and assists in retaining the moisture. In its absence clay soils become hard and packed, difficult to work, and such soils suffer from the least drought.

Many experiments have been made to show that organic matter makes soils more retentive of moisture and I need only to refer to one series of experiments made at the Hawaiian Experiment Station to determine the water holding capacity of soils containing varying amounts of organic matter.

In the experiments referred to the hill lands which contained far more organic matter than the valley lands absorbed 66 per cent of their own weight of water while the valley land absorbed 45 per cent. At the end of one month the former still retained 55 per cent of the water absorbed, while the latter retained but 37 per cent of the total amount absorbed. It is thus seen that the soils containing a large quantity of organic matter not only absorb, but retain for a longer time more water than do those soils poor in organic matter.

This is of the greatest importance to all plantations that cannot irrigate, but must depend on rainfall. Even on the east and north coasts where the normal rainfall is sufficient ordinarily for the production of large crops of cane there are occasional droughts that affect crops very seriously. There are two methods by which the organic matter may be renewed in the soil, first by ploughing in cane trash, which is not always practicable, especially where insects and diseases are numerous, and second by raising some crop specially for the purpose of ploughing into the soil. The chief of these crops are the various leguminous plants which are grown with great profit by many agriculturists in various parts of the world. In Louisiana it is a general practice after one crop of plant and one of ratoon cane have been harvested to sow cow peas. These mature in the few months of summer and are plowed into the soil in the autumn before planting cane again. There is lost thus but one year, or one crop of cane. In Mauritius, some long-growing legume is planted, and the land allowed to rest for several years, the kind of legume planted depending on the number of years it is desired that the land shall rest.

Besides adding organic matter to the soil these legumes have the property of taking nitrogen from the atmosphere and storing it in the leaves, stems and roots of the plant, and this valuable ingredient is stored in the soil when the crop is plowed in. Now nitrogen is the most expensive element in fertilizers; in fact the nitrogen alone

in a fertilizer selling say for \$50 per ton is worth in the neighborhood of \$30 to \$35. In other words two-thirds of the value of the fertilizer is in its nitrogen.

Stubbs estimates that one crop of cow peas adds to the soil 100 pounds of nitrogen per acre which at the price of Sulphate of Ammonia in Porto Rico is worth approximately \$17.50. In Cuba the writer grew a great many varieties of legumes; the cow peas, velvet beans, and varieties of canavalia were the most promising, the former producing about five tons of green weight per acre, while the canavalia produced ~~was~~ of much greater weight.

The Station is making experiments with cow peas and velvet beans, as being probably the two most suitable crops for our sugar plantations. Either of these can be planted in the Spring after the cane is harvested and the vines plowed up in the autumn in time for the fall planting.

At the most, under this system, but one crop of cane will be lost, and not even that when land is usually left over for fall planting.

There are other benefits attributed to green manuring besides that of adding organic matter and nitrogen to the soil. As a rule the legumes are deep rooting plants and bring up available material from the sub-soil. Again it is believed that a crop grown after the cane has been cut will assist in eradicating the many root diseases that affect the cane so adversely.

8. THE COLONIA SYSTEM.

As it is the desire of the members of this Association to bring to bear on their fields more scientific cultivation, and to improve agricultural conditions in general, I must say a few words regarding the system of renting land to colonos for a number of years, and the relation it bears to the efforts you are making toward improvement. What is said is not intended as a criticism, for there are many factors influencing this practice that are known only to the plantation authorities themselves, but simply to call attention to the disadvantages so that they may be understood, and avoided wherever possible.

Many companies that own the land from which they derive their cane for milling lease the land to colonos at so much per acre, the principal condition being that all of the cane raised on the land shall be sold to the companies at a stipulated price, which price is based on the weight of the cane, and has no reference either to the sucrose content or to the purity of the contained juice. In other words the companies owing the land give up their control over all cultivation practices, fertilization, etc., and this control passes to a great number of individual planters, independent of each other and to a great extent independent of the central authority. There is therefore no uniformity of methods of cultivation and no provision for enforcing methods of insect and disease control. The authorities can make recommendations, but can not enforce demands. It will be practically impossible for this Station to reach these colonos and no measure of reform can be introduced with a reasonable degree of confidence.

Measures for the control of pests and diseases to be effective should apply to whole plantations or whole districts, otherwise, one or two colonias whose owners refuse or fail to observe precautions may continually act as sources of infection to surrounding districts.

Again the mill is deprived of the cane that would be delivered to it were the colono progressive and used modern methods of cultivation.

Under the system of buying cane on weight only, there is no incentive to the colono to produce a cane of superior sweetness or maturity. He is paid on weight and his whole effort is to produce weight. We have seen the evil effects of this system; as a rule we have found that that part of a given plantation which is cultivated by administration is in a better condition than those parts leased to colonos, and the effect is at once seen in the mill in passing from plantation cane to colono cane by a lowering of the purity of the juice and consequently a diminished yield.

Again, while the land cultivated by administration is planted to cane that is suited to local conditions, the colonos cane is often badly mixed and contains varieties of cane that give large weight but low sucrose and purity. This accounts in a large measure for the rapid distribution of certain varieties of cane which are

not suited to cultivation in this island, and to the low purity and yields of factories grinding cane from many planters.

It would seem that where it is advisable to lease the land to individual planters the companies should to a large extent retain control of the cultivation. With an expert cultivator in the employ of each of these large companies, and control of cultivation vested in him, much better results could be secured than are possible at present.

Again the tenant having a lease of land only for a few years, it is not to his interest to build up the land, and as a result a destructive system of cultivation is adopted which leaves the land at the end of the term in an impoverished condition.

On the whole it appears to me that the manufacturer of sugar in Porto Rico is in advance of the cultivation. No pains are spared to erect the best machinery and to get the best results from cane delivered to the mills. As a rule all operations are under the supervision of experts, and modern sugar-making has reached a high degree of perfection. But the fields have been neglected—your immediate efforts should be directed to the fields and if the same amount of skill, and expenditure of money is brought to bear on the cultivation, as has been centered on the manufacture great benefit will result.

The principal observations and recommendations in this report are as follows:

1. Most of the cane soils are sedimentary, and while of great original fertility many of them have become exhausted by long cropping.

2. For fall planting the land is usually well prepared but is often improperly prepared for spring planting.

3. Plowing is too shallow, deeper plowing would improve both deep and thin soils.

4. Furrow system should be introduced in hill lands, sandy and well-drained soils, followed by mechanical cultivation.

5. Cultivation is inadequate and expensive, owing to the system of planting in holes.

6. The white cane is too weak for most Porto Rico fields and conditions, and efforts should be made toward finding more suitable canes.

7. Insoluble fertilizers should be applied in the furrow before planting and all fertilizers should be well distributed in the rows or around the stools of cane.

8. The meth borer and root diseases are widely spread and are doing much damage.

9. More attention should be given to the selection of seed, and destroying seeds which are borer infested or suffering from root disease.

10. The manufacture of sugar in Porto Rico has advanced more rapidly than the production of cane. Immediate efforts should be directed to the fields.

San Juan, P. R., April 30th 1911.

J. T. CRAWLEY,

Director.

FIRST REPORT
OF
ENTOMOLOGIST OF EXPERIMENTAL STATION

FIRST REPORT OF THE ENTOMOLOGIST.

By D. L. VAN DINE.

INTRODUCTION.

The extent of the area devoted to the cultivation of sugar-cane is, in itself, a great impetus to the development of the insect pests of the crop in that an unlimited food supply is given. The continuous cropping practiced in cane culture furnishes the pests with a continuous food supply, and the lack of a decided change in seasons provides for their uninterrupted development. Further, the cane crop does not lend itself readily to the use of active measures against pests.

Theoretically there are three methods of combatting an injurious insect. One method has for its foundation the fact that where the "natural balance" between the plant and the insect has been disturbed, the balance may be turned in favor of the plant by introducing into the field the natural enemies of the insect pest. No one who has studied the factors that govern insect development can doubt the important role held by the enemies of a species in checking its undue increase. Further, we have illustrations in actual practice where this method has been successfully employed. The study, however, is a complicated one and we cannot assume that this method will be successful in the control of all injurious species. Too many adverse factors contribute, unfortunately, to make it otherwise. Indeed, the unsuccessful efforts in the use of this method far outnumber the successful efforts. Just as a plant-feeding insect might increase to such an extent as to overcome finally its plant host, if not checked by its parasitic and predaceous enemies, so the natural enemies might more often overcome the plant-feeding insects were it not for their enemies or the secondary parasites. The increase of a plant pest is not always due to the absence of its natural enemies, but to other factors, and, in this case, natural control would not apply. The successful use of the natural method of control is dependent upon certain factors. The most hopeful condition is that in which an insect pest is of foreign origin and has been introduced into a new territory without its natural enemies, this implying that the secondary parasites of the natural enemies of the pest have also been excluded. Then by searching for and finding the special enemies of the pest and introducing them into the infested territory, taking care to exclude the secondary parasites, one may hope for success, if the pest will adapt itself to the new conditions and establish itself under them. In an insular territory the possibilities are greater than the undesirable secondary parasites, as a class, will not be so well represented as in a continental territory. Since Porto Rico is an insular territory and since the pests of the sugar-cane, for the most part, are introduced species, the chances for success in introductions of natural enemies equal those in countries similarly located, as, for example, Hawaii.

A second method for the destruction of insect pests is the use of active or direct measures; that is, the actual reduction of the numbers of the pest by mechanical and artificial means. With many crops this is a feasible method. The use of insecticides is a direct method of insect warfare and many efficient insecticides have been worked out for the control of certain insect pests. As regards sugar-cane, the inability to get into or through a field after the crop has attained any extended growth and the cost of labor to treat thousands of acres were it possible to do so, does not permit of the general use of direct measures in dealing with sugar-cane insects.

A third method or head under which various measures for the control of insect pests may be classified is that of prevention. Preventive measures apply particularly to the pests of field crops and especially to the insects affecting sugar-cane. This method consists of those plantation operations and measures which, when carried into effect, eliminate the pests from the field, or at least keep their numbers below the danger point. In sugar-cane culture the selection of non-infested seed, the picking of white grubs when plowing for a crop, and the burning of trash are all preventive measures. A direct measure is often put into practice as a prevention that is, a badly infested center of cane might be treated at a relatively high expense in comparison to the value of the cane in the area treated, in order to prevent the infestation spreading to the surrounding cane.

The ability to employ any particular remedy or measure of control depends entirely upon the species of insect under consideration and the nature of its injury to the cane. In undertaking work on the insects affecting cane in any particular locality, we must begin, then, with a study of the insects themselves, their relation to the cane under the local conditions, and the manner and extent of their injury. It is essential to know, also, the status of the local cane species in other cane countries, their habits and work under other conditions and the methods employed or the natural checks that occur elsewhere for their control. Aside from the status of the local pests in other countries, the insects affecting cane found elsewhere which do not occur in Porto Rico must be determined and the question of preventing further introductions considered. Having determined the cane pests, the study of the use of any one or all measures for their control must be given attention in the light of local conditions of climate, habits of the species, methods of cultivation of the cane and the natural checks that occur or those which may be influenced to bear upon the problem.

While the semi-tropical climate of Porto Rico and a continuous cropping season favor insect development, a disadvantage in comparison to Louisiana, where the months of winter constitute a check to insect increase, its insular position is a decided advantage both as regards efficient work in preventing further noxious introductions and in assisting the intentional introductions of beneficial species.

The planters will find preventive measures the most effective means of control at the present time. The introduction of special parasites to control an insect pest is a method that requires time and very careful work. Therefore, such natural checks do not lend themselves for immediate use at a time when a remedy is most needed. Natural control will relieve the planters of the great expense of preventive and direct measures in those instances where an effective enemy of the pests is obtained and established.

This report deals with the insects found affecting sugar-cane in Porto Rico in as much detail as the literature of the subject and the investigations of the Station to date will allow. The time covered is from September 22, 1910, the date of my arrival from Louisiana, to April 1, 1911.

Acknowledgments are given for the determinations of species and for cooperation in the work received from Dr. L. O. Howard, Chief of the United States Bureau of Entomology, Washington, D. C., and from Mr. W. D. Hunter, in charge of southern field crops insect investigations of the same Bureau at Dallas, Tex. Further, I am indebted to Dr. R. C. L. Perkins, entomologist of the Hawaiian Sugar Planters' Experiment Station, Honolulu, for information relating to the Mexican parasites of the moth stalk-borer.

DISCUSSION OF THE INSECTS.

There have been observed four species of insects which must be rated as doing serious injury to the cane. The one most general in its distribution, and likewise most serious in total amount of injury considering all of the estates of the island, is the moth stalk-borer, *Diatraea saccharalis* Fab. A second insect, whose distribution is also general, is the sugar-cane mealy-bug *Pseudococcus sacchari* Ckll. Practically all fields may be considered as infested by these two species. The per cent of infestation varies in different localities, according to the conditions that prevail as regards varieties, methods of cultivation, climatic conditions and the age of the cane.

The third and most acute insect problem is the white-grub injury at the roots of the cane. Several beetles of the family *Scarabaeidae* have been collected in the

cane fields, and the injurious white grub is a species belonging to this family and is a member of the genus *Lachnosterna*. While the white grub is restricted somewhat in its distribution, the injury is serious in those fields affected by the ravages of the insect, and the evidence that the extent of its injury is increasing gives reason for concern.

The fourth species referred to, namely, the mole-cricket or La Changa, *Scapteriscus didactylus* Latr., is found over the entire Island, but is restricted in its distribution in the cane fields both by its breeding and by its feeding habits. Favorable breeding places for this insect are loose or sandy soils and the species feeds to an injurious extent only upon germinating seed and the young cane. The Changa does not abound in stiff or clay soils and does not injure cane that has attained some height and the root system and stalks of which have become somewhat hardened.

Other insects which have been observed attacking sugar-cane in Porto Rico are a weevil stalk-borer, *Metamasius hemipterus* Linn.; a shot-hole stem borer, *Xyleborus* sp.; a weevil root-borer (undetermined); a scale-insect, *Targionia sacchari* Ckll.; grass-worms (*Lepidoptera*—undetermined); and a plant louse, *Aphis* sp.

In all, notes have been obtained on some ten species of insects injurious to sugar-cane in Porto Rico, the most acute being the injury by the white grub at the roots and the most general that of the moth stalk-borer.

THE SUGAR-CANE MOTH STALK-BORER, EL BARRENO DE LA CAÑA, DIATRAEA
SACCHARALIS FAB.

The insect is found within the cane stalk and is the white caterpillar of a moth. The species is identical to the sugar-cane borer of Louisiana and is common throughout the West Indies. It is probably of South American origin. The insect is known also as an enemy of cane in Argentina, Peru, British Guiana, and Mexico.

LIFE HISTORY AND HABITS.

The eggs are deposited by the female moth upon the leaves of the cane. They are laid in clusters, the number of eggs in a cluster varying from two or three to twenty-five. Morgan found in Louisiana as many as ninety-five eggs in a single cluster, and the same authority estimated that the number of eggs laid by a single female moth would average 294, deposited in numerous clusters. The eggs are flat in shape and almost circular in outline, and are arranged in the cluster like shingles on a house; that is, one overlapping the other. An individual egg is about 7.5 mm. long by 5 mm. wide. The egg cluster appears as a light discoloration on the leaf, and is, at first, rather difficult to find. The clusters are deposited on both the upper and the under surfaces of the cane leaf along the mid-rib. The usual position is on the under side of the upper leaves and towards the tip, though the location differs as greatly as does the number of eggs deposited in any one place. The eggs hatch in from 5 to 10 days, depending upon the temperature and the moisture conditions which prevail.

When first hatched the caterpillars or borers are very small and comparatively dark in color. They are found outside the cane stalk among the terminal leaves of the cane. After feeding to a slight extent on the epidermis of the young upper leaves, the small borers work down to the stalks, eating a way between the stalks and the closely wrapped leaves. They usually enter the stalks at the base of the leaf-sheaths, and many times at or near the eyes. Sometimes a young borer will make several attempts to enter a stalk, but when once inside the entire development is passed within the stalk. The borer feeds upon the inner tissues of the stalk and in so doing prepares a tunnel which runs lengthwise. The size of the tunnel increases with the size of the borer. When full-grown, the moth stalk-borer is about one inch in length. It is yellowish-white in color, has six pairs of legs and there are dark-brown spots on the body. The length of time required for the development of the larva or borer is from 20 to 30 days.

The full-grown borer prepares an opening in the rind of the cane stalk. It then enlarges the portion of its tunnel or gallery near this opening and plugs the outlet with the frass or excrement made by its borings. In this location, within the stalk the larva or borer transforms to the pupa or chrysalis. The pupal stage in the de-

velopment of the insect is an inactive one and is the time during which the insect changes from the borer to an adult or the moth stage. The chrysalis is dark-brown in color and is about seven-eighths of an inch in length. The duration of the chrysalis stage is from 7 to 10 days. The adult moth emerges from the cane stalk through the opening in the rind made by the borer previous to pupation. When the moth emerges from the cane stalk, it leaves the empty brown case or shell of the chrysalis behind in the gallery.

The adult moth is straw-yellow in color. It measures about one and one-fourth inches in width when the wings are spread. The forewings are darker than the hindwings. When the moth is at rest, the wings are held close to the body and in this position they form an acute triangle. Along the terminal margin of the wings are parallel lines of dots. There are brown lines on and between the wing-veins. The male moth is darker and smaller than the female. The adult moths emerge from the cane stalks during the night. The moths are active during the night. During the day they rest in the seclusion of the cane. Mating occurs usually the night following the emergence from the stalk. Egg-laying begins almost immediately thereafter and may continue for several successive nights. The moths are not strong flyers. The female, when heavy with eggs, is particularly restricted in her flight. The eggs for the following brood of borers are laid in the immediate neighborhood where the adult moths originated.

The sugar-cane stalk-borer is recorded as infesting corn, sorghums, Johnson grass (*Sorghum halepense*), guinea corn, and grama grass.

DEVELOPMENT.

The time required for the complete development of the moth stalk-borer will depend upon the conditions of temperature, moisture, and food that exist. The development will be more rapid during the warmer months and, also, in soft cane that is making a good growth. The exact time necessary for the life-cycle of the moth stalk-borer in Porto Rico has not been determined as yet. It will be found to vary between 32 days and 50 days. Even at the maximum time given, it is to be seen that several successive broods may develop during the growth of a single crop.

DISPERSION.

On account of the restricted flight of the adult moth, the natural distribution of the insect is not rapid over a plantation. The pest spreads out gradually from an infested center. During the growth of any one crop, one portion of a plantation will not suffer an invasion from an infested portion. The moth stalk-borer is usually distributed over a plantation by artificial means, that is, either in the infested cuttings taken from field to field for seed, or in infested stalks which are scattered along the way when the cane is hauled from the field to the central. Within any particular field, the insect may originate from damaged stalks which are discarded when harvesting the crop, from the old stubble, from the tops in the trash, from infested seed cane which has been imperfectly covered, or from the infested cuttings discarded when planting.

INJURY TO THE CANE.

The total amount of loss to the sugar planters from this insect is considerable. The pest is generally distributed over the island and the infested areas in any particular locality are not restricted in extent. For the reason that the moth stalk-borer has acquired more or less of a definite status, its injuries do not give to the planters as much concern as the more acute, and therefore more noticeable, injuries of the white-grub or the changa.

The first injury from the moth borer is the reduced stand of cane due to the destruction of the eyes in the cane used as seed. Further, the borer wounds in the cuttings will allow an entrance to disease and decay, which will lower the percentage of the germinating eyes in the infested seed.

The stand of cane is further reduced by the infestation of the young shoots after germination. The infestation of the young shoots originates from the moths which have emerged from discarded stalks, from discarded cuttings intended for

seed, from cane tops in the trash of the previous crop, from the old stubble, and from nearby infested cane. This injury to the young shoots is indicated by the dead hearts, or central whorl of leaves, which by pulling are easily drawn from the shoots. The injury is caused by the young borers, which hatch from eggs deposited on the young leaves by the parent moth, entering the shoots down between the central whorl of leaves and encountering the newly forming "bud" of the stalk. The shoots thus infested are killed as a rule. If the young shoots have formed small joints at the base, the cane will sucker sometimes, and this will help the stand, but at best, the crop is put back for several weeks in proportion to the number of shoots infested.

The most serious injuries resulting from the work of the moth stalk-borer are the actual reduction in the weight of the cane, the loss from badly damaged stalks which are discarded when harvesting, and the effect of the fermentation which ensues on the purity and sucrose content of the juice. The Station has a project under way relating to the effect of the moth stalk-borer injury on the purity and sucrose content of the cane juice.

Aside from the above injuries, the stalk-borer wounds in the stalk offer a means for the establishment of diseases, borer infested stalk are more difficult to mill, and are more easily broken in working the crop and by the wind.

CONTROL.

Natural.—Specimens of sugar-cane moth-borers killed by a fungus parasite were collected by the writer at hacienda Fraternidad, Guanica Central, on October 20, 1910. This beneficial fungus, specimens of which were referred to Prof. R. Thaxter, of Harvard University, has been determined by him as *Cordyceps barberi*. Since the above date this parasitic disease of the moth stalk-borer has been observed to be generally distributed in the sugar-cane districts of the island.

An hymenopterous egg-parasite, *Trichogramma pretiosa* Riley, of the moth stalk-borer occurs in Barbadoes and Mexico and is reported to be an effective check to the development of the numbers of the borers in those countries. This parasite has not been recorded from Porto Rico, but the species has a wide geographical distribution. It is parasitic to the eggs of the cotton boll-worm, *Heliothis obsoleta* Fab., in the southern United States. Dr. Perkins, in Hawaii, informs the writer in a recent letter, that Koebele collected other egg-parasites of the moth stalk-borer, as well as the above species, in Mexico and that these parasites are highly efficient in reducing the numbers of the borers in that country.

The Station plans to investigate carefully the parasites of the moth stalk-borer. This work requires time and careful study and the planter is urged to employ the preventive measures for the control of the moth borer until such time as the Station can inform him of the exact status of the natural enemies which occur in Porto Rico at the present time or can assure him of the establishment of introduced parasites and the extent to which the preventive measures may then be modified or discontinued.

Climatic.—Under the equable climate that obtains in the island, the development of the borer is practically continuous, there being no dormant period in its life-cycle such as is found during the cold months of winter in Louisiana. An extended period of dry weather no doubt constitutes a check to development. Morgan found that in Louisiana the length of the egg-laying period of the adult depends largely upon the amount of moisture in the atmosphere, dry weather being prejudicial to the life of the moth. The borers are in less numbers and are capable of doing less injury in dry, hard cane, than in succulent cane which is making a good growth.

Mechanical.—The greatest direct check to borer development is a mechanical one, that of the effect of the grinding on all those in the stalks which are harvested and which pass through the mill. Were it practical to grind every stalk of cane harvested from any particular field and to burn all of the trash left in the field, there would be left practically no borers to attack the succeeding crop.

Artificial.—Plantation methods constitute the principal measure of control at present for the moth stalk-borer. The trash should be burned in all fields where this insect is common. The burning should be done when the trash is dry in order

that all discarded stalks left in the field may be destroyed. The immature joints in the tops should also be destroyed thoroughly.

Seed selection.—The seed cane should be cut from the fields showing the least borer infestation. The cuttings for seed should be selected and all cuttings showing evidences of borer should be discarded. The seed selection should be made at the place of harvest and the discarded cuttings should be piled with the leaves and tops and, when dry, should be burned. Only the selected seed should be carried to the new field to be planted. Since the moth-borer is largely distributed over a plantation in the stalks which are infested, and which have not been destroyed, and not to any great extent by the flight of the adult moth, it is very important that all borers in the harvested field be destroyed and only clean seed taken to the new fields.

Careful covering.—If it is not practical to discard all infested cuttings in the seed selection, the seed should be well covered with soil when planted, to prevent the adult moth emerging from the cuttings. It is impossible for the adult moth to emerge to the surface and escape, after completing its development within the cutting, if the seed is well covered by finely divided soil when planted. The seed need not necessarily be planted deep, but all of the cutting should be covered by at least one inch of soil. On irrigated plantations, the irrigation water accomplishes this nicely. This is not the case in the control of the weevil stalk-borer, since the adult weevil upon emerging from the cutting can find its way to the surface of the soil, even though the cutting be well covered.

Plucking.—The presence of the moth stalk-borer is indicated in young cane by the dead "hearts." This injury reduces the stand but it is the effect of the succeeding generations on the growing crop that is serious and that must be prevented. To a great extent the increase of the borer can be prevented by cutting out these young shoots which show the dead "hearts." As soon as the dead centers appear in any number, an examination should be made to determine the cause, since the Changa injury produces the same symptom. If the moth stalk-borer is found to be the cause, laborers should go through the fields and cut out the infested stalks as indicated by the dead "hearts." Care should be exercised to cut low enough to get below the tunnel or gallery of the borer in order that the caterpillar or borer may be removed with the shoot. The work should be done before the borer has transformed to the adult moth and emerged from the young shoots. The shoots which are thus removed should be carried along by the laborers in a sack to the callejones and left there at the ends of the rows. These plucked shoots should then be collected and carted from the fields and destroyed by burning, feeding to stock, or otherwise. In Louisiana the cost of cutting out these infested stalks in young cane was estimated to be 20 cents per acre.

THE MAY-BEETLE OR WHITE-GRUB. EL CACULO Ó GUSANO BLANCO, *LACHNOSTERNA* SP.

The young or grubs of several species belonging to the beetle family *Scarabaeidae* are to be found about the roots of cane, coffee, grass, certain weeds and some trees in Porto Rico. The abundant species found about the roots of cane belongs to the genus *Lachnosterna*. The adult of the sugar-cane grub feeds upon the cane leaves at night and is a characteristic May-beetle, brown in color and about seven-eighths of an inch in length. The genus *Lachnosterna* comprises many species which, from their appearance in temperate zones in the month of May, have received the common name of May-beetles. The young or grub is known as the "white-grub" and is called locally "el gusano blanco."

DISTRIBUTION.

The identity of the white-grub in the cane fields of this island and its distribution in other countries have not been definitely established. The species is not identical to the grubs infesting sugar cane in other cane growing countries.

The data available at the present time indicate that the white grub has been a pest to cane in Porto Rico for at least 20 years. (Fernando López Tuero. La Caña de Azúcar en Puerto Rico, su Cultivo y Enfermedad, 1895.) Little information is to be found regarding the development, food plants, breeding habits and habits of flight of this insect, neither has the varia-

tion in numbers in different localities been explained. There is also a variation in numbers in the same localities in different years. The factors of location, food plants, soil, climate, and natural enemies that do or may influence the distribution must be determined.

LOCAL DISTRIBUTION.

The white grub has been observed locally in serious numbers at the roots of cane at Eureka (Mateo Fajardo), Filial Amor (Francisco P. Quiñones), and Acacia (Guánica), in the San German Valley; at Santa Rita (Guánica) and Florida (Guánica), in the Guánica districts; at Potala (Aguirre), in the Ponce district, and at Buena Vista (Central de Canóvanas), at Loiza (Central de Canóvanas), at Fortuna (Fajardo), and Margarita (Santiago Veve, Fajardo), on the East Coast. Further investigations will undoubtedly show this insect to be more generally distributed throughout the districts of the island than is now apparent.

LIFE HISTORY AND HABITS.

The life history of the white grub is imperfectly understood. This is true not only of the local cane species, but of white grubs in general. The prolonged development and the subterranean habits of the larvae render observations difficult.

The female beetle enters the soil to deposit her eggs. The eggs are laid singly several inches beneath the surface of the soil among the roots of sugar cane, certain weeds and some trees. The eggs are nearly round in shape, whitish in color and resemble large pearls. They hatch in a few days time after being laid.

Upon hatching from the eggs, the young grubs or larvae feed upon the roots of the infested plants. The grub is white in color with a brownish head. The hind segment of the abdomen is large and smooth. The fore part of the body is supplied with three pairs of short jointed legs. When not active, the grub lies upon its side with the body curved, the head and the rear ends nearly touching. The white grub or larval stage is the prolonged period in the development of the insect and occupies at least a year.

When fully developed, the white grub prepares an earthen cell within which it changes to a pupa. This inactive stage is the time during which it transforms from a white-grub to the adult May-beetle.

The life cycle of the white grubs in a temperate climate is believed to average about three years, though the time varies according to climatic and soil conditions. Since the insect hibernates some six months of this time during each year in a cold country, it should seem that the life cycle, under the local conditions which afford continuous development would not be longer than one-half of this period.

DISPERSION.

The main factor restricting the dispersion of the insect, judging from the habits of the genus *Lachnosterna* in other countris, is the fact that May-beetles possess no great impulse of migration. The larva or white-grub is incapable of any migration in the soil because of its limited powers of locomotion and only by the flight of the adult can the distribution of the insect become naturally extended. The adults are night flyers, but do not move in swarms and, so far as known, fly no great distance. That is, there is no movement of migration of the insect, even in the winged adult stage, such as we find in many winged insects and some larvae, as, for example, the army-worm. The flight is, in the main, from the locations suitable for larval development to the food plants of the adult and from thence, in turn, to the breeding place again, in this case, the cane fields.

Aside from the absence of a migration impulse, the feeding habits would influence the distribution of the insect. Many species of *Lachnosterna* possess a great variation in food habits in the larval and adult stages, that is, the larva or white-grub will feed at the roots of one plant, grass for example, and the adult only upon the foliage of certain other plants, trees for example. From this habit, the female might fly a comparatively long distance from the trees upon which it was feeding to soil suitable for egg-laying, since, by instinct, locations suitable for the larval development would be selected. Since the Porto Rican species does feed to some extent on cane leaves, there is a greater restriction in its distribution than

would result did the adult beetle seek a food plant somewhat removed from the cane field and, in turn, from that location, seek, by flight, cane fields wherein to deposit eggs for the following brood of white-grubs.

Occurring at the roots, the insect has not been transported from district to district in seed cane, as has been the case with the moth stalk-borer and the mealy-bug. It is probably the fact that the infested areas represent centers of long standing, reinfested, according to the favorable conditions for development that existed, from previous broods that have developed in the same or nearby fields. As the numbers have increased the circle of infestation has widened, or the insect, finding especially favorable conditions in some particular field or locality, has developed accordingly and created a new center.

INJURY TO THE CANE.

The most serious injury from white-grub attack is the pruning of the root system of the cane plant. The adult feeds upon the leaves of the cane at night. An indirect injury is the entrance to disease afforded by the wounds at the roots caused by the feeding of the white-grub.

The disease most likely to be complicated with the white-grub is the prevalent root-disease. In situations where this disease exists the white-grub injury would aggravate the fungus trouble. The remedies suggested by Mr. Johnston, pathologist of this Station, for the root disease, namely, seed selection, good cultivation, and such plantation practices as burning off and trashing, would, however, have little effect on lessening the numbers of the white-grub. In fact, improved soil conditions and a more extended rooting-system would no doubt favor white-grub development. A vigorous growth of cane would not so readily show the effect of white-grub injury as a poor growth or one affected by root disease, but the favorable factors offered for development would make it only a matter of time before the pests would increase to such numbers as to be able to overcome the most vigorous growth. For this reason, the control of the white-grub remains a distinct problem from that of the root disease. The relation is one in which the injury to the roots by the white-grub will increase the injury from root-disease, if root disease is present, but freedom from root-disease will still leave the white-grub injury a problem to be considered.

The injury is at present comparatively restricted in extent, but in so far as we know now, this insect is capable of doing an equal amount of injury throughout the cane fields of the island, if once established, as is now experienced within the infested areas.

CANE GRUBS OF OTHER COUNTRIES.

Regarding the beetle grubs attacking sugar cane in other countries, there is a species in Louisiana, *Ligyris rugiceps*, known as the sugar-cane root-beetle, the adult of which injures the young shoots in the spring of the year by eating into the stalk just beneath the surface of the ground in a manner very similar to our mole-cricket or chunga. The larva infests the roots of the cane, but is not particularly injurious, feeding on the older partly decayed portions or upon other partly decayed vegetation in the soil. The beetle belongs to the same family as the species under discussion, but is not a true May-beetle, belonging to the group commonly known as "hard-backs." The adult remains in the soil, appearing above in flight at night to pair. The remedies in Louisiana are to plow late in the fall, in order that the grubs in the soil may be exposed and killed by frosts; too off-bar, that is, throw the dirt away from the stubble in the spring, to bring the eyes at or near the surface, thus hastening germination and lessening the chances for the beetle to attack the young shoots; to cultivate frequently, thus disturbing the beetles in the soil; to keep down grass and other food plants of the beetle along ditch banks and headlands, and to pick both larvae and adults when plowing. The collection of the insects and destruction or treatment of other food plants are the only points in these remedies that are at all applicable to our species. Blackbirds are considered the most efficient enemies of the Louisiana cane beetle. They feed upon the beetles and grubs when the same are turned out in plowing. Titus mentions both an hymenopterous and a dipterous parasite of *Ligyris rugiceps* and further says that predaceous ground

beetles of the family *Carabidae* were found feeding upon young white-grubs in the field. Careful note has been made of this last point.

There is a West Indian species of *Ligyrrus*, known as a "hard-back," *Ligyrrus tumulosus*, which Ballou records as a cane pest in Barbadoes, but I can find no details as to its injury or the methods, if any, employed in its control.

In Demerara there are two cane beetles, *Ligyrrus ebenus* and *Dyscinetus bidentatus*, and the latter species causes heavy damage but no study has as yet been given to the insect or its control. Quelch has recently undertaken work for the cane planters there and we will have, later, the results of his investigations.

Two species of *Scarabaeidae* attack the roots of cane in Cuba but they have not as yet been studied.

The only beetle of this family attacking cane in Hawaii is the species *Adoretus tenuimaculatus*, introduced from Japan and known as the Japanese beetle. The insect is never found in numbers in cane and only occasionally does it occur at all in the cane field. The adult feeds upon the leaves of horticultural plants, for the most part, and the grub lives in the soil feeding upon decaying vegetation. Koebele discovered some 12 years ago a fungus disease parasitic to this insect. This parasitic fungus has been widely distributed in Hawaii, and, in the more humid districts, has become generally established and is an active agent in the destruction of the beetle.

In Java there is a cane grub, *Apogonia destructor*, which, in habits, is similar to the local species, that is, the adults feed upon the cane leaves at night and the larvae feed at the roots in the soil. It is reported that the adult of the Java species appears in November and deposits eggs shortly after that time. The larvae are credited with a comparatively short active period, about two or three months, the adults re-appearing in the spring. The remedy in Java is collecting the adults after they appear and before egg-laying. A dipterous parasite of the genus *Maciera* occurs in Java as an enemy of the Java cane beetle.

A common Indian species, *Serica indica*, attacks the roots of cane in the larval stage and Lefroy records parasites of that species. Nothing can be found concerning the work of the grub in the cane fields but a family of wasps (*Scolidae*), parasitic to white grubs, is represented by several common species in India.

The most serious cane pest in Queensland at the present time is the so-called "cane grub," *Lepidiota albohirta*. Large areas are reported to have been injured severely this last season. Collecting the beetles is the chief remedy employed, though treatment of the soil with carbon bisulphide and potassium cyanide is being tried. A wasp, *Deilis formosa*, closely related to the Indian species mentioned, has been recorded by Froggatt as destroying the underground cane grub in Queensland. The wasp burrows down to the grub in the soil, stings and paralyzes it, lays an egg on it and goes away; the larva of this wasp, on hatching from the egg, devours the cane grub and pupates there.

The writer is in correspondence with Mr. D. F. Mann, in charge of an estate in Mexico (Estación de Chavarillo), who says that cane in that district is severely injured by a grub closely resembling the rice root-grub of the southern United States. Mr. Mann states that the Mexican cane grub also thrives in grass lands and that its control is a very difficult matter. Experiments will be undertaken by Mr. Mann in plowing out and picking the grubs, in picking adult beetles when they appear in the spring, and in the use of carbon bisulphide in the soil. Mr. Mann will furnish the Station with the results of his work.

CONTROL.

Natural.—The blackbirds are the most important natural enemy of the sugarcane white-grub noted by the writer thus far. Since the adult May-beetle or caculo is active at night, hiding in the soil during the day, and, since, the white-grub or gusano blanco is at the roots of the cane, beneath the surface of the soil, the birds have access to the insects only at plowing time. However, at plowing time, an immense number of the insects are eaten by these birds which follow closely behind in the newly turned furrows and work industrially over all the ground that is turned up. These birds are most valuable to all planters and to agricultural interests generally. Their protection should be taken up seriously by every plantation manager.

There are two species of the blackbirds: The one known locally as "Judío," because of the enlarged upper part of its bill, is according to Prof. H. W. Henshaw, Chief of the Biological Survey at Washington, identical to the so-called Savanna Blackbird and has the scientific name of *Crotophaga ani*. The same authority informs me that the other species, known locally as "Chango", or "Mozambique", is *Holotrichopus brachypterus*.

The latter bird is, according to the planters, the most active in searching for white-grubs behind the plows. The "Judío" is, however, a most useful bird in that it feeds also upon the ticks of cattle, and the changas when the latter work at or near the surface of the ground. In fact both birds are valuable members of the Porto Rican fauna and, while it is advisable to introduce and establish in this island other beneficial birds and natural enemies, it is still more advisable to protect and foster the forms we have already, which are established, and which have proved their worth.

Upon returning from my first visit to hacienda Santa Rita (Guánica), I took up the matter of introducing from Hawaii the fungus parasite of the so-called Japanese beetle of that country. The first shipment of this fungus parasite arrived per S. S. "Carolina" from New York on January 12, 1911. The material was received from Mr. Edward M. Ehrhorn, Honolulu, entomologist of the Hawaiian Board of Agriculture. Up to this date (Ap. 1/911) we have not succeeded in obtaining cultures of this fungus, either artificially or in the breeding cages, on the local species of May-beetle. Another request for additional material has been made to Mr. Ehrhorn.

In the United States, Forbes, of Illinois, and Riley record insect parasites of the larvae of *Lachnosterna*. This is the genus to which the Porto Rican sugar-cane white-grub belongs. These and other authorities mention also the destruction of white grubs at certain times by parasitic fungi. The Station plans to investigate carefully the work of these natural enemies. When the identity and geographical distribution of our cane species is worked out definitely, we will then attempt to locate special natural enemies.

The study of the parasitic control of an insect pest is a complicated and difficult subject and success cannot be counted upon. This fact does not, and should not, however, prevent us from following out all possible chances that may lead to control; and as a definite phase of ultimate control, which I believe can be predicted, the natural enemy studies of the white-grub will be undertaken.

Artificial.—The good work of the blackbirds in the destruction of white-grubs behind the plows is materially increased by turning swine and fowls into white-grub infested fields at Guánica Central. This is a wise practice and if such live stock can be purchased reasonably at the time needed, allowed to feed upon the grubs during plowing time, and the swine at least, supplied with some green food, they should be in good condition to sell at a profit when their season of usefulness in the fields is passed.

The most important control work in progress at Guánica Central is picking the grubs by labor behind the plows, digging out and picking the grubs from badly infested stubble and restricted centers of infestation where the cane is being actually overcome, and the picking of the adult beetles from the cane leaves at night during the time the adults are active.

Guánica Central has extensive experiments under way to test the use of carbon bisulphide as a subterranean insecticide against the grubs. Favorable results have been obtained but the general use of bisulphide is limited by the cost of such treatment (the cost ranging between \$20 to \$30 per acre) and by the injurious effect of the insecticide on the growing cane when injected down into the center of the stool, the place where it is most effective. Guánica has undertaken further comparative experiments with other substances from the standpoint of the killing power on white grub, the effect on the growing cane, and the cost of the material.

Another line of control suggested is that of the destruction of the adult beetles by spraying young cane and other food plants with an arsenical mixture. The adult has been observed feeding upon plants other than cane, particularly upon pig-weed (*bleto*), *Anaranthus* spp., and many beetles would no doubt be killed by an application of a solution of some arsenical compound to the leaves of these plants.

The Station is making provision for the study of the life and seasonal history

and development of the sugar cane May-beetle and its habits as regards food, flight, soil, etc., and the results of these studies will suggest further remedies.

THE MOLE-CRICKET OR LA CHANGA, *SCAPTERISCUS DIDACTYLUS* LATR.

Because of its widespread injury and variety of food plants, La Changa is the most commonly known and is generally considered the most pernicious insect pest in Porto Rico. The Porto Rican mole-cricket is recorded also in Cuba, Trinidad, Jamaica, Haiti and St. Vincent, in the West Indies and in South America. The insect seems to have attracted little attention outside of Porto Rico, though one early reference speaks of its ravages in St. Vincent as early as 1837. (Johnston. Proceedings Entomological Society of London, 1837.) Harris, 1862, in speaking of the species, says "In the West Indies, extensive ravages have been committed in the plantations of the sugar cane." (Insects Injurious to Vegetation, 3d Edition, Boston 1862.) Fernando López Tuero discussed its injury to sugar cane in Porto Rico in 1895. (La Caña de Azúcar en Puerto Rico, su Cultivo y Enfermedad, Río Piedras, P. R., 1895.) Busck made a brief note of the mole-cricket in Porto Rico in 1900. (Bureau Entomology, U. S. Dept. Agriculture, Bulletin 22, 1900.) The most extended report concerning this species is by Mr. O. W. Barrett in 1902. (U. S. Experiment Station Bulletin 2, Mayaguez, P. R.)

LIFE HISTORY AND HABITS.

In discussing the moth stalk-borer and the May-beetle we were considering insects that have what is termed a complete metamorphosis, that is, these insects in their development from the egg to the adult, or perfect insect, pass through a series of separate and distinct stages. For example, the moth stalk-borer upon hatching from the egg is a larva or caterpillar. From this stage it passes to another stage, that of the pupa or chrysalis. The chrysalis is not only distinct in form, but is inactive and does not feed. In this stage of development there is a breaking down of all, or nearly all, larval organs and a building up of the organs of the adult month which, when completed, produces the winged, active, perfect insect. So also we found in the life-history of the May-beetle an egg, a larva or grub, a pupa, and an adult or May-beetle stage.

Passing to the mole-cricket or La Changa we have to consider, in its life-history, an entirely different state of affairs. The mole-cricket has an incomplete metamorphosis, that is, in its development from egg to adult we encounter no definite and well separated stages. After hatching from the egg, the mole-cricket is active and feeds throughout its entire development. The immature stage is called a nymph and this stage of development is marked off by simply a series of moults, or a shedding of the outer covering of the body, whereby the immature insect gradually attains the size and form of the adult. The young mole-cricket has, further, the same feeding habits as the adult and is found in the same situations. As regards mouth-parts, legs, and body divisions, the young mole-cricket resembles the adult. The main characteristics that distinguish the young or nymph from the adult mole-cricket are the smaller size, the variation in color and the absence of wings in the nymphs. By every moult these differences become less marked until the adult stage is reached.

There is much speculation regarding the life history and habits of mole-crickets. They are adapted by structure to live beneath the surface of the ground. Especially is this true of their modified forelegs, which are highly specialized for burrowing and for cutting roots. By aid of these broad front legs, the insects are able to form burrows underground in which to travel from place to place, to feed, and to breed. As a group, the mole-crickets have a fondness for moist soils. The depth of their burrows or galleries depend upon the moisture content of surface soil, that is, in dry weather they burrow deeper. Owing to the difficulty encountered by the insect in tunneling through a stiff or clay soil, it is always more numerous in loose or sandy soil. In sugar-cane fields the "Changa lands" are usually the alluvial deposits, or "made" soil, along river banks. When burrowing near the surface, as they do in moist soil or after rains, the mole-crickets will leave the surface of the ground traversed by a network of intersecting ridges or mounds of soil, indicating the progress of the insects beneath. Through loose soil they can make surprisingly rapid progress.

The eggs of the mole-cricket are deposited in an enlarged part of one of its terminal galleries at varying depths beneath the surface of the ground. Some 100 eggs are laid by a single female in a heap. They are described by Barrett as being "of a dirty yellowish color, elliptical in outline, smooth, and about 3 mm. in length by 1 mm. in diameter." The eggs are said to be laid during January, February and March in Porto Rico, and to hatch in about two weeks.

The nymph or young changa is almost white when first hatched and begins at once its work of destruction to the roots of plants in the vicinity of the burrow or egg-chamber. The nymphs are very active and this, together with their prolonged development, renders a comparatively few individuals capable of a great deal of destruction. The development of the nymphs of the mole-cricket is recorded as ranging from 12 to 18 months.

Under normal conditions the young or nymphs do not leave the soil. The winged adults, however, very frequently leave the soil and at certain seasons of the year are attracted to lights at night. The development and habits of the changa remain to be determined.

DISPERSION.

The unusual subterranean power of locomotion has been a great factor in the spread of this insect. Depending upon the looseness of the soil, the pest can spread out in all directions from any particular center of infestation. At certain seasons of the year, under favorable climatic conditions, the winged adults leave the ground at night for flight in immense numbers and thus the insect has become more widely distributed.

CHANGA INJURY TO CANE.

Fortunately the changa injury to sugar cane is limited to the germinating seed and to the young cane shoots. It works by eating into the seed cane, destroying the eye, or by cutting into the young shoots just below the surface of the ground. Shoots thus injured are indicated by the dead "hearts." As soon as the young shoot begins to harden and form a stalk, the mole-cricket does not appear to have the ability to damage the plant further. In tobacco plantations, on the other hand, changa injury begins in the seed-beds and continues in the field throughout the growth of the crop.

MOLE-CRICKET INJURY IN OTHER COUNTRIES.

Koebele records injury to seed cane in Hawaii by a moth-cricket, *Gryllotalpa africana*, a species allied to our Changa. (The Hawaiian Planters' Monthly, Vol. XV, No. 12, 1896.) The Hawaiian species is not at all common in cane fields, its injuries being confined to limited areas along watercourses where the soil is abnormally wet. Under such conditions the seed cane is known to have been destroyed. It has not been necessary to pay any particular attention to the mole-cricket injury in Hawaii. The Hawaiian mole-cricket is also recorded by Lefroy as the abundant species in India, but no mention is made of any injury to crops. (Indian Insect Life. Calcutta, 1909.)

The North American mole-cricket, *Gryllotalpa borealis*, is a serious pest at times in pasture lands and attacks also corn, vegetables, cereals, flowers and the tubers of potatoes. The principal remedy employed against this species is a preventive one and consists of the rotation of crops.

The European mole-cricket, *Gryllotalpa vulgaris*, has long had the reputation of being a serious pest of gardens and meadows in moist places. No effective remedy is recorded, due no doubt to the imperfect knowledge of the life-history and habits of the insect.

CONTROL.

Natural.—Blackbirds feed upon changas both at plowing time and in cultivated fields when the insects are working at or near the surface of the ground. Lizards also devour many of the insects. Long periods of drought no doubt would prove a check to their development. The existence of the insect beneath the surface of the

ground and the fact that it is active, for the most part, only at night, affords the pest special freedom from attack by its enemies. It may be that predaceous insects and animals, other than those occurring in Porto Rico, will be found that will prey upon the Changa.

Artificial.—The Porto Rican practice of planting seed cane in a vertical position, with at least one eye above the ground, insures the germination of this eye and prevents injury from La Changa. Tuero states that the insect avoids burrowing up over a ridge and that planting "en' banco" has that advantage over the hole or "en hoyo" system. Probably shallow planting of tops in "Changa" lands will give the greatest protection, since the leaf-sheaths about the stalk will protect the eyes and will allow them to germinate and the young roots and shoots to obtain a start before being subjected to injury. Clean cultivation in and about a field, keeping down especially the food plants of La Changa, such as "yerba dulce," will do a great deal towards preventing the increase of the pest.

At Guánica it has been found that by dipping the ends of the cuttings in ordinary tar immediately before planting, and then wiping the tar down the seed, prevents injury from the Changa.

THE SUGAR-CANE MEALY-BUG, QUERESA Ó PIOJO DE BOLSA BLANCA,

PSEUDOCOCCUS SACCHARI CKLL.

The mealy-bug is a small soft-bodied, pinkish insect without wings. It belongs to the scale-insect family, *Coccidae*. It does not occur singly but is found in a cluster on the lower portions of the cane plant. The cluster of individual insects is covered by a conspicuous mealy-like white secretion. The mealy-bugs are found, as a rule, about the crown or beneath the lower leaf-sheaths and are often attended by ants, particularly the ant "hormiga brava," *Solenopsis geminata*. The relation between the ants and the mealy-bugs is a protective one: As stated, the adult female is wingless and the insect is transported from field to field, mainly, on the seed cane. On the seed, the insect occurs about or beneath the eye or beneath the leaf-sheath. When abundant on seed cane, the young mealy-bugs have been known to kill out the germinating eyes beneath the surface of the ground. The insects congregate about the young shoots and roots in young cane and the vitality of the plant is seriously affected by their feeding. The insect feeds upon the plant by inserting its thread-like beak or proboscis through the epidermis of the plant and sucking or pumping the juice from the inner tissues. The punctures or wounds made by the feeding process offer an entrance to the tissues for various diseases.

CONTROL.

The burning off of the trash and the selection of seed cane from the fields least infested by the mealy-bug, as noted under remedies for the moth stalk-borer, are important in reducing the numbers of this pest. Where a plantation is generally infested by the mealy-bug and clean seed can not be obtained, it may be necessary to treat the seed with an insecticide. Experiments will be made by the Station for the purpose of determining methods that will prevent the spread of the mealy bug.

In Australia there occurs a lady-bird beetle, *Cryptolaemus montrouzieri*, which is a special mealy-bug feeder. This beneficial beetle has been established both in Hawaii and in California by Koebele. The beetle was introduced into the Louisiana cane fields last season to feed upon the sugar-cane mealy-bug of that country. This Station, in cooperation with the Bureau of Entomology of the United States Department of Agriculture, will import the beetle into Porto Rico.

THE WEEVIL STALK-BORER, METAMASIVS HEMIPTERUS LINN.

This cane beetle is a weevil, the grub of which exists as a borer in the stalk of the cane in a manner similar to that of the caterpillar of the moth stalk-borer. The Porto Rican weevil stalk-borer is related to the Hawaiian sugar-cane borer,

Sphenophorus obscurus Boisd. Unlike the Hawaiian species, the Porto Rican weevil borer does not appear to be 'numerous.' Ballou records an allied species, *Metamasius* (*Sphenophorus*) *sericeus* Oliv., as occurring in Barbadoes. (West Indian Bul., 1905.)

The adult weevil is brown in color with dark markings on the thorax and wing covers. It is about one-half of an inch in length. The head is prolonged into a beak or proboscis.

The eggs are laid singly just beneath the rind of the stalk. The Hawaiian species often deposits the eggs in the leaf-sheaths also. The young grub or weevil borer, on hatching from the egg, bores into the cane stalk, the tunnel increasing in size as the grub develops. The tunnel runs lengthwise of the stalk.

The grub or borer is footless, pale yellow in color, wrinkled in appearance, and with the hind part of the body swollen. When full-grown the grub prepares a cocoon of the fibre of the cane stalk and within this cocoon it transforms to the pupa or inactive stage. In time the adult weevil emerges from this cocoon within the tunnel and works its way out of the cane stalk. The development of the weevil stalk-borer is much longer than that of the moth stalk borer. The Hawaiian species of weevil borer requires some three months for development from the egg to the adult.

The softer canes suffer more than the harder varieties and the Hawaiian species works more in moist fields or in wet weather than during the dry season or in the dry localities. The injury from the weevil borer does not usually manifest itself in Hawaii until the cane is from six to nine months old. It is interesting to note that Muir has recently introduced a parasite into Hawaii for the weevil borer of that country, after an effort of some three years in the Malay Archipelago.

A common method of preventing the increase of the Hawaiian weevil borer is to collect the adult weevils by hand, women and children being employed. The adult weevils are found during the day hiding down between the lower leaf-sheaths and the stalk and from these situations they are collected by the laborers. Care should be exercised in this work to avoid breaking down the growing leaves of the cane.

In Fiji, where the Hawaiian species is found also, a method of baiting the beetles is employed. This consists in splitting pieces of cane stalks about 12 inches long and placing them along the edges of the field and within the field at intervals of about 15 feet. Koebele reports that seven little Indian girls collected and brought in over 16,000 beetles in four hours from split cane. The split cane appears to increase in attractiveness as the juice ferments. A further point regarding the split cane is that the females usually infest the pieces heavily with eggs and the resulting young grubs perish as the pieces become dry. The split cane ceases to attract the weevils after it becomes dry.

The stripping of the cane is believed to minimize the injury from the weevil borer in Hawaii.

The weevil stalk-borer is not apt to increase in Porto Rico on those plantations where the recommendations made for the control of the moth stalk-borer are put into effect.

THE SHOT-HOLE STALK-BORER, *XYLEBORUS* SP.

This small beetle is brown in color and about one-tenth of an inch in length. It is identical to, or closely related to, the well-known "shot" borer common throughout the West Indies. The species has not been observed in any numbers in Porto Rico. The specimens that have been collected have been found in comparatively few stalks in isolated localities.

The adult shot-hole borer perforates the cane stalk, forming a net-work of tunnels within. The eggs are laid in these galleries and the succeeding generations develop within the stalk.

It is reported that the insect does not attack cane unless the stalk has been previously injured or is affected by disease.

THE SUGAR-CANE ROOT-BORER (UNDETERMINED).

In making examinations about the roots of cane for white-grub conditions, the writer has repeatedly turned up the grubs of a weevil which closely resemble the West Indian sugar-cane root-borer, recorded by Ballou in Barbadoes as *Diaprepes*

abbreviatus. The identity of the species can be determined definitely when adults have been bred. No particular damage has been found as yet which could be credited to the species but, since the root-borer of Barbadoes has proved to be a serious pest at times, the exact status of the local species should be determined.

It is reported that when the root-borers are numerous, they destroy practically all of the underground stem of the plant. The root system does not appear to be injured, the attack being confined to the stem of the root and the plant dies for want of a proper connection between its feeding roots and the growth producing leaves.

MISCELLANEOUS SUGAR-CANE INSECTS.

In addition to the insects which have been discussed somewhat in detail, the writer has collected an aphid or plant-house, *Aphis* sp.; a scale-insect, *Targionia sacchari* Ckll.; and grass-worms, (undetermined); from sugar-cane in Porto Rico. In one or two field the grass-worms were seriously injuring some of the young cane by defoliation. This injury was in no case extensive and so long as the central whorl of leaves are not eaten, the young cane will push ahead and soon reach a stage of growth where the grass-worms cease to be a factor. Leaf-hoppers, of which the abundant species is *Tettigonia similis* Walk., have been collected on grass in and about cane fields. It remains to determine all of these miscellaneous species and to work out their possible relation to the cane.

SUGAR CANE INSECTS OF OTHER COUNTRIES AND THEIR EXCLUSION.

There exist in other cane growing countries many species of insects injurious to cane not at present found in Porto Rico. As examples, I can mention the Hawaiian leaf-hopper, and the weevil stalk borer, the Louisiana root-beetle, the Demerara giant stalk-borer, the Trinidad frog-hopper, the Queensland root-beetle and the moth stalk-borer, and a host of others present on cane in other countries which, if established in Porto Rico, might become serious pests. The principal avenue through which other cane pests might enter Porto Rico, is that of introductions of seed cane. The activity in cane countries in the development of new varieties and the desirability of obtaining promising new canes for trial, have led to the practice of the interchange of seed. This practice is accompanied by danger and should either cease, each country seeking to develop its own varieties, or the introductions of cane should be made only under the supervision of one capable of judging whether or not the shipments should be allowed to enter or be rejected and destroyed. The general inspection of all plant introductions is important to the sugar planter, since many species of injurious insects are general feeders and a species might be introduced on a plant other than cane, which, when established in the island, would turn its attention to the cane crop. The trade relations of Porto Rico with other countries is increasing and the danger from the undesirable insect introductions will increase in direct proportion. Though the work of plant inspection and quarantine is apart from the entomological work of the Station, I mention the point because of its direct interest to sugar planters and to indicate that the Station realizes its importance and will cooperate in every possible way to make the Insular exclusion regulations a success.

D. L. VAN DINE,
Entomologist.

Rio Piedras, P. R., April 3, 1911.

FIRST REPORT
OF
PATHOLOGIST OF EXPERIMENTAL STATION

FIRST REPORT OF THE PATHOLOGIST.

By J. R. JOHNSTON.

Examination of a number of sugar plantations of Porto Rico has made it so evident that many diseases well known in other cane countries are present and widespread that it seems desirable to present to the planters such knowledge of these maladies of the sugar cane as may be available. Such a discussion will also be of service to us in pointing out the important subjects for experimental work.

Before entering upon the detail of the diseases themselves it may make the discussion clearer if first I describe briefly the manner in which these parasites are able to affect the cane, and also the method of applying remedies to cure or overcome these diseases. It may in the first place be necessary to state that the cane stalk consists of a mass of soft tissue composed of tiny cells or cavities, among which are imbedded numerous fibres running lengthwise in the cane. These fibres are much more crowded toward the outside of the stalk than at the center, and altogether serve to strength the cane. Enclosing this mass of soft tissue and fibre is a more or less definite layer of thick-walled cells, which, together with the external hard cutinous covering, forms the rind of the cane.

The fibres besides being formed to give strength to the stalk, also serve to conduct the water supply from the roots to the leaves. For this purpose they are constructed of cells, some of which form a continuous tube. The fibres run from the roots up the stalk and send branches out into all the leaves. The cells or cavities surrounding these fibres do not form tubes, but are closed cavities, which, however, contain living vegetable matter. The walls of the cells are filled with tiny pores, through which the water or plant juice may pass when necessary, so that there is a constant change going on in all the living plant tissues. In the leaves the same tissues are present, but arranged in a different way for a particular purpose. In addition to the constituents of the stalk the leaves have also numberless green bodies, which have the power insunlight of absorbing gases from the air and combining them in the leaf with the water to force the necessary compound for the life of the plant. If sunlight was absent, or if for any reason these green-colored bodies failed to develop properly, or if in sufficient water was present the plant would suffer from lack of nourishment, and if the unfavorable condition lasted long the plant would die. As a proper development of the cane is necessary to a proper formation of the sugar in the cane, it is easy to see how important these points are. The leaves are flat and wide, so that they present a large surface of green matter to the sunlight, and thus have a large area busy in the manufacture of food material necessary for the plant. The sugar occurs in the stem of the plant. The roots absorb the necessary water from the soil. It will thus be seen that the three commonly recognized part of a plant—the roots, stem and leaves—must all be in the best of health in order to obtain the maximum amount of sugar.

Fungi are in themselves plants, but very small ones, so small that it is necessary to use a microscope to make out their structure, although a mass of them is recognizable without the aid of a glass. These fungi consist of a vegetable part made up of many very slender branching threads, and a fructifying part, which consists chiefly of the tiny reproductive bodies or spores. Fungi are of many forms and of different modes of living. Some grow on the soil, some in water, some on the surface of other plants and some within the tissues of other plants. In the latter case they

derive their food directly from the plant in which they are living, and consequently it is more or less injured.

On the cane plant are various fungi, some merely growing on the surface of the stalk or leaf, some within the dead leaves or stalks, and others within the living tissues. Among these different kinds it is necessary to ascertain which are actually doing damage to the cane plant; if growing on the surface of the green leaf they merely reduce the amount of green surface so much; if within the tissues of the leaf they are destroying the green bodies which are necessary to the formation of food for the plant; if within the stalk they are destroying the sugar content or destroying the fibres or tubes by means of which the water is brought from the roots to the leaves; and if within the roots they are destroying the tissues that absorb from the soil the water necessary to the life of the plant.

A perfectly healthy cane plant is well protected against the fungi entering the cane tissue. The stalk has a very hard rind, which very few, if any, fungi can penetrate, and there is a constant activity in the cells of the roots, stalk, and leaves which is injurious to any fungus trying to enter. If for any reason the activity among the cells diminishes or ceases, or if by any means the roots are injured or the stalk cracked or the leaves torn or pierced by insects, or for any similar cause the vitality of the plants is lessened the fungus makes its way into the tissues with little difficulty. The eating of the cane roots by the white grub and the chaga, and the wounding of the stalk by the borer are frequent causes of fungus infection. A drought prevents enough water from entering the roots and passing to the tissues of the stem, thus lowering its vitality. Some poisonous material may be in the soil and pass into the roots in solution with the water and a consequent injury may result as in the case of alkali and of limy soils.

Now, just as there are fungi which affect the plant in different ways, so are there different methods of trying to kill the fungus without injuring the cane. Various poisonous mixtures sprayed on the surface of the sugar cane will kill those fungi living on the surface, but will not affect those growing within the tissues. For the latter purpose the only means is to cut off the diseased portion. On such plants as the orange or mango this is practicable, but it is impossible in any practical work with cane. One can remove infected leaves and leaf-sheathes to a certain extent, and in some cases this is recommended. There is, however, no more direct method of treating these diseases. In similar cases with other diseases many investigators have tried to grow varieties of the crop resistant to the disease, and this has also been tried with the sugar cane, but there is still a great deal more to be done along this line.

At present the known means of treating any cane diseases are the destruction of all the diseased material that can be done in a practical way, the best cultivation of the plant so that it will have the right condition for a healthy growth, and the selection of varieties most resistant to the diseases. Along the line of destruction of the diseased material there will be noted in the discussion of the various diseases the removal of the leaf-sheathes on the cane stalks and on the selected cane seed, and the removal of diseased stubble from the field. In connection with good cultivation there will be discussed thorough preparation of the soil, liming the ~~land~~ ^{soil}, and drainage and irrigation. In the matter of selection of varieties the little that has been done will be mentioned under the various diseases.

In the study of various maladies affecting the cane particular care has been taken to ascertain the most serious of these troubles and the amount of injury caused by it. The root disease undoubtedly not only causes the most loss, but is very widespread and requires considerable care to overcome. The damage due to this disease I believe is much underestimated by most of the planters. This is owing partly to the fact that the injury is often confounded with that caused by the white grub, and partly to the fact that it is difficult to estimate the loss on cane which is merely reduced in size and is not a total loss. To ascertain the relation of the white grub to the root disease, the entomologist, Mr. Van Dine, has compared notes with me and we have examined cane together. It seems to be a fact that cane affected by the white grub is more readily susceptible to the root disease. But it is also true that much cane is affected with this disease when there are no white grubs present nor any signs of injury by them. These facts render a consideration of the white grub in the matter of treatment for the root disease necessary only so far as it is

one of the many factors in weakening cane and making it more susceptible to disease. There are during the present season fields in different parts of the island that are almost a total loss due to the root disease, as well as many fields in which the stand has been much reduced owing to the action of the root fungus. This trouble is so important that I have discussed it in considerable detail in other paragraphs, considering both the nature of the disease and method of combatting it.

In addition to the root disease there is another matter that should be presented to the planters immediately; that is the matter of cutting the seed, of seed selection and of treatment of seed. Frequently planter find that some of the same seed is not growing, and so they go over the field again, putting in new seed. In one field which I examined 273 seed out of 1,245 failed to grow. This trouble is not at all confined to one plantation, but is fairly common in all parts of the island, at least wherever little care is used in selection and preparation of the seed for planting.

The reason for the seed failing to grow is sometimes said by the planters to be a drought. It is true that dry weather is bad for growing seed, but one of the reasons why it is bad is because the seed is weakened and succumbs readily to the fungus attacks. This fact can not be emphasized too strongly especially in the case of poor seed. In examining this poor seed one or more of several diseases is found. The cane from which the seed was taken may itself have been infected or the seed may have become infected after planting. Careful cutting of the seed and selection of the seed from healthy cane, together with treatment with some solution to prevent disease-producing fungi from entering will prevent this trouble to a large extent.

In cutting the seed the work should be so done as to crack the cutting the least possible. Cracks in the seed provide places for the entrance of disease-producing fungi and render difficult the proper application of a disinfectant. There are two principal methods of cutting the seed; the most common being that with an oblique blow, and the other being with a straight blow. The first method is the most convenient, and if properly done has been found satisfactory, especially by the experimenters of the Hawaiian Sugar Planters' Association. With the cane held obliquely in the left hand, the right hand holding the knife is brought down and at the same time toward the body. The blow is accomplished chiefly by a short, quick motion of the wrist. The ordinary worker in cutting cane gives a rather long, sweeping blow with the arm, which in comparison with the other method produces more cracks in the cane. It must be observed, however, that the style and the condition of the knife are the most important features. An instrument with a blade that is wide and thin and that is kept sharp is the best in all cases.

The method of cutting seed with a straight blow is the more inconvenient method and depends for its value fully as much upon the condition of the knife. The cane is cut on a block, which requires the worker to remain in the same place and to have the cane brought to him or else to move the block from time to time. It should be noted that the men planting the seed are more apt to bruise or crush the slanting end than a straight end, as they often attempt to push the seed into the soil. For this reason the straight-end seed have an advantage over those with oblique ends, but aside from this the latter appear to be the easier to prepare and to have as few cracks as the former. It is believed that the men cutting the seed and the condition of the knife used are the really vital points in the cutting of the seed. It should be observed that the straight cut should not be made unless upon a block.

In selection of the seed, it should be noted whether the stem is full and healthy looking, whether the eyes are sound, and whether the leaf-sheathes are free from discoloration. Fructifications of the rind fungus and of the stem-rot fungus may appear on the stem and thus indicate its diseased condition. The eyes may be discolored or actually rotted due to the fungus of the stem-rot disease. All seed affected with either of these two diseases should absolutely be discarded and even burned up to prevent further spread. If the leaf-sheathes are discolored with large bright red spots with black centers—thus indicating the disease known as red spot of the leaf-sheath—they should all be removed before planting the seed. The question has often arisen as to whether top seed was more desirable for planting than bottom seed. Aside from the matter of disease, it is generally agreed that top seed is the best, but it should be noted that in some fields the top of the cane is much more diseased than the middle or even base of the cane. In old stands of cane the top dries out readily, and the rind fungus or stem-rot fungus appears there first. All

this must be considered, and if such top seed can be selected that is free from these diseases, or can be made practically free from them by tripping off the leaf-sheathes, then it is better than seed taken from lower down on the stalk. If top seed of this sort is not available, it is possible that cuttings lower down on the same stalk may be good.

After selection of good seed it is desirable under all circumstances to treat it with some application that will prevent the entrance of fungi from the soil. In several cases when I dug up seed that had failed to grow the cuttings were infected with the rind fungus, and occasionally the eyes were dead owing to the stem rot, but in the majority of cases the trouble was due to the pineapple disease. This had apparently entered the ends of the seed from the soil, and then the entire inside of the seed had rotted, causing a blackening of the tissues, which gave off a strong pineapple odor. Treatment of the seed with Bordeaux mixture before planting would have prevented this. The expense of this treatment is so little and the benefits so great that the method of doing it is given in detail in other paragraphs.

In regard to the other diseases found on sugar cane, it may be said that several of them are believed serious, but need further investigation before much can be said definitely as to the loss caused by them. Besides the full treatment of the root disease, brief descriptions of the other diseases are given, together with a description of a method for making and using Bordeaux mixture.

ROOT DISEASE OF SUGAR CANE.

1. *Nature of the disease.*—The root disease is first noted by the appearance of the leaves; in stead of being broad and green they tend to become narrow and to turn yellow from the edges inward. They stand closer together than ordinarily, and altogether the stool presents a dwarfed appearance. Examination of the base of the stalk reveals the leaf-sheaths whitened and adhering to the stem owing to the presence of fungous mycelium. The sheath tissues are fibrous and rotted, showing none of the firm characteristics of a healthy green leaf-sheath nor of one ordinarily dried through lack of water. By pulling up a stool the white, branching, thread-like mycelium of the fungus is easily seen in the earth and adhering to the roots. Often the roots may be so rotted by the disease that the stools may be pulled up with ease. Frequently, however, some of the mycelium may be found on roots and stalks without apparently having caused any rotting or any other serious injury to the plant.

The fungus lives in the soil or in decaying pieces of sugar cane, and where living cane roots are available passes into them and dries out the tissues. The leaf-sheaths close to the ground are frequently wet, and in the natural course of events die. This condition gives a good foothold for the root fungus, which grows up the dead leaves and along the wet stalk sometimes to a height of two or three feet. These rotting leaves about the lower part of the stalk are detrimental to the growth of the cane, especially by killing the adventitious roots at the lowest joints and the eyes higher up. The effect of the fungus is much greater when it attacks the young cane. If a good foothold is obtained the stool becomes dwarfed and grassy-looking and is of very little value. On the other hand, the fungus may be found growing at the base of old cane, which to all appearance is perfectly healthy. The effect of the fungus depends upon the vitality of the cane at the time it is attacked. The root fungus may be found on apparently healthy cane, which in an unfavorable state of soil aeration, soil moisture, atmospheric condition, or injury has been hindered seriously in its further development.

2. *Fungus causing the disease.*—Several different fungi have been found in connection with the root disease of the sugar cane both in Porto Rico and in other cane countries. No one has yet demonstrated the exact relationship of these fungi to the disease or shown the amount of loss due to each.

The form most widely accepted as being the prime cause of root disease is *Marasmius sacchari*. As the mycelium found in connection with this disease only occasionally shows any fructifications it is not always possible to name the fungus causing the trouble. In Porto Rico *Marasmius sacchari* is held to be chiefly responsible, while other fungi, such as *Schizophyllum commune*, and the *Sclerotium* of the leaf-sheath, causing red rot, are suspected of complicating the trouble. Although the fruiting parts of these various fungi differ a good deal, yet the vegetative part which is responsible for most of the injury is essentially the same in appearance and

in effect upon the plant in each case. Any fungi found in the cane field and resembling a mushroom may well be suspected of having some relationship to the root disease. This applies to those forms found apparently growing from the soil and those on dead cane, as well as those on the living cane stalks. Fungi seen growing in cane trash are too often considered as perfectly harmless. It must be remembered that certain forms may grow in dead vegetable matter ordinarily, but they may also pass from the soil to the living tissue, particularly if those living tissues are by any chance not in a vigorous condition of growth.

3. *Loss due to the root disease.*—Neither in Porto Rico nor in any other country so far as is known have experiments been made to estimate actually the loss by this disease. To count the number of stools affected in any given field is an easy matter, but to estimate the actual damage by the presence of the disease is difficult and impossible of accuracy by direct methods. So many other factors influence the relation of the root fungus to the cane that it renders the problem of ascertaining the loss by the root disease a complex one. Only by a series of experiments completely under control can this be done. While the amount is difficult to determine, it is easy to ascertain the fact that in many localities it is at least very serious. In several localities fields of very poor cane have been seen affected by the root fungi, but under otherwise apparently normal condition for good growth. Not even the white grub was present, or in certain fields present in such small numbers that it could not be said to be responsible for all the trouble. In very many places where the average cane is good there are stools of very small cane, a condition that can often be attributed mainly to the root fungus. Also in many stools of good cane there are frequently some stalks that are seriously damaged by the fungus.

From the condition of one field, where the loss due to this disease was probably 75 per cent, to other good-appearing fields, in which the loss is less than 1 per cent, there are all gradations. Naturally in certain fields there is no loss whatever that can be attributed to this cause. In other fields of good appearance I have counted 15 out of 57 stools affected and 8 out of 35; that is about one-fourth of the stools. The loss in each stool probably in these cases averaged 10 per cent, thus making a total loss of $2\frac{1}{2}$ per cent. This it must be remembered is in fields considered healthy. In cases where it is recognized that good cane is not being obtained, the amount frequently averaged 5 and 10 per cent and higher. Usually in the most severely attacked fields some other unfavorable condition is present, so that it is impossible in those cases to know how much to attribute to the root disease.

Spread of the disease.—The root fungus is chiefly spread through the soil and on pieces of diseased cane. Its distribution by growing through the soil is necessarily slow. By the scattering of trash and the plowing up of the stubble and leaving it in the field the spread of the fungus is more rapid. In the case of the fruiting or flowering parts of the fungus, which always appear above ground, the spread would be very rapid if its fructifications were common. Flies and other insects frequenting these fructifications carry the spores from place to place, and thus may spread the fungus some distance. Fortunately these fructifications are not very common, so that this method of distribution is of less importance than that by cane trash. In addition the men working in the field may carry on their shoes or on tools, such as hoes and knives, some fragments of the mycelium. In practical methods for controlling the fungus, the fructification may be neglected, but the greatest care should be taken that affected cane trash is not by any means scattered over the fields.

Great care should be taken in the selection of seed free from any root disease. In the case of stalks affected by the root fungus only the uppermost joints of the cane are safe to use for seed. The loss of one infected seed would not be serious in itself, but when it is remembered that this means a new point of infection from which the disease may spread through the soil to adjacent stools, its importance is more readily apparent.

Among some planters there is a custom of planting between the rows of old cane, the stubble of which has not been removed. There is no question but what the cost of getting the seed into the soil is less than by other methods, but it must also be noted that to leave the old stubble in the field is one of the surest ways of spreading the disease, and consequently of lessening the new crop of cane.

TREATMENT.

Burning of trash.—As the fungus lives in old cane leaves and stubble which remains in the field after the crop is removed, it would be desirable to destroy it if

some practical means could be devised. In some places the trash is burned as a means of getting rid of these fungi, and commonly in Porto Rico the trash is burned in order to get it out of the way. It must be noted that by burning the trash a good fertilizer is lost, and especially a good means of improving the mechanical condition of the soil. In considering the advisability of burning the trash to reduce the amount of root disease, it should be determined whether the conditions are such as to warrant it or not. The root fungus grows on almost all kinds of soils, so that the variety of conditions is considerable. In the cases where the disease is so bad that the tonnage of cane is considerably reduced by it and the soil is fairly rich and not too heavy, I would recommend burning. Wherever the root disease has shown very little effect on the cane it is not desirable to destroy the trash merely by reason of the small amount of disease. And even if the fungus disease is serious on light sandy soils or heavy soils the plowing in of the trash and consequent improvement of the mechanical condition of the soil would so increase the vigor of the cane as to be a partial protection against the fungus. In addition to this, in the case of the heavy soils the application of lime as mentioned in following paragraphs would be of material benefit. In questions of this sort it must be remembered particularly in regard to the root disease that the best preventative is the best condition of the soil for the nutrition of the plant.

Liming.—After a field is cleaned of all the stubble and cane trash by burning there often remains much root fungus in the soil, as has already been mentioned. In the case of any soil that will stand liming that should be done. Heavy soils or soils rich in humus can usually stand a great deal and be benefited by it. Unslaked lime should be used. The most practicable plan for applying the lime is to empty the barrels of lime on the fields and cover over the piles with earth until they are partially slaked. As soon as the lime becomes reduced to a powder it should be immediately spread over the field and as soon as possible plowed in. Rains will benefit the operation by helping to mix the lime well into the soil. The application should be made as soon as the lime is in such a powdered condition as to render its distribution easily carried out. The amount of lime will vary with the condition of the soil, but 2,000 pounds to the acre may be considered as a low average.

If, now, instead of preparing the land for a new plant crop it is desired to ratoon, essentially the same methods are adopted with the exception that the lime is applied only about the old stools. Either hoeing in about the stools or working the lime in by some mechanical means will aid in mixing the lime with the soil.

Drainage and irrigation.—The condition of the soil as to its moisture content naturally bears an important relation to the vigor of the plants growing in such soil. Sufficient moisture to permit vigorous growth of the cane will do a good deal toward throwing off this disease. If the cane is suffering from lack of water, or from too much water up to a certain extent, the root fungus will gain a good foothold on the cane roots. In "poyal" lands and in many other lands proper drainage must be arranged for. This depends not only upon the situation of the land, but also upon the character of the soil. Particularly upon the south side of the island the matter of irrigation also often plays an important part. Insufficient water, as well as too much water, so weakens the plant as to allow great activity to the fungus.

Rotation of crops.—One year lying fallow would benefit the field immensely. In this time the root fungus would be much reduced in amount, and in addition the soil would be in better physical condition for the new crop.

An advantage over allowing the field to lie fallow would be the planting of some crop for green manure, such as cowpeas. When the crop reached a good growth they should be plowed under. By this means the land would be allowed to rest from the cane, the root fungus would be reduced in amount, and a good fertilizer would be returned to the soil.

Corn has been suggested as a crop to rotate with cane as the product would be of some direct commercial value. The land would not be benefited, however, as with the cowpeas or other leguminous crop. It has, moreover, been suspected in Barbados that the root fungus of the sugar cane attacks cane, in which case there would be an added reason for not using corn in rotation with cane.

The question of some crop to alternate with cane and furnish immediate returns has not been well worked out, and for the present it is deemed best to use solely the leguminous plants for the purpose of improving the soil.

Trashing.—In stools that have been dwarfed and rendered practically worthless

by the root disease there is nothing one can do but to pull up the stool and destroy it. Oftentimes, however, the root fungus is found affecting the leaf-bases in fairly good stalks of cane. In order to prevent further injury it is advisable to remove all the lower affected leaves and clean away all debris from the bases of the stalks. This permits the air and sunlight to get in in sufficient amount to prevent much further injury by the fungus. Care should always be taken, of course, not to remove the green leaves or in other ways to injure the living tissues of the plant. No trash removed in this operation should be allowed to remain in decaying piles between the rows.

Ratooning.—There is no question but that the ordinary method of ratooning increases the amount of root disease in the field. The fungus having obtained a foothold on the plant cane is given an excellent opportunity to increase its vigor in the stem when the first crop is removed. When the new shoots come out the fungus is already present and inside the tissues of the plant as well as outside. If the cane is allowed to go to second or third ratoon, the condition is even worse. On the other hand, if no fungus is present on the plant cane the first ratoon should be very good, other things being equal. Also, if the plant canes are limed and light cultivation about the stools is practiced the ratoon should be in good condition. It is in cases in which infested stools are allowed to remain year after year that the land becomes thoroughly infected with the disease and serious injury results to the crop. Such fields should be replanted after burning the trash and after being well cultivated with lime plowed in. Or better than replanting, they should either be allowed to rest as already suggested or planted in other crops. In a badly infested field only a fair crop of cane can be obtained in the best of seasons, and should unfavorable conditions prevail the results to the crop would be more than ordinarily serious.

Disease-resisting varieties.—In Porto Rico there appear to be no varieties of cane entirely resistant to the root disease. Certain varieties may have appeared to suffer less than others, but they have not been tested long enough to prove the resistant qualities.

In Hawaii the Yellow Caledonia has been more resistant than other varieties, while not being entirely immune to the disease.

In Barbados canes Nos B-6048, B-1529 and B-208 were in 1908 considered the most resistant to the root fungus. In Antigua in 1910 the varieties known as Sealy Seedling and D-95 seemed to be fairly resistant. In Louisiana in 1910 D-74 and D-95 showed some resistance to the diseases.

These examples are given as illustrations of the fact that some varieties are seen to be able to withstand the effect of the root fungus. It is not intended to suggest that the planting of these canes would be worth while. As yet not enough is known about them to make such a recommendation. It is believed that by the various experiments being carried out at this time on different plantations in Porto Rico more definite information will be obtained on the subject. It must be remembered, however, that even a so-called resistant variety might succumb to the root fungus if it was not given good cultivation and other conditions favorable for good growth.

Isolation of diseased areas.—Very often the root disease is found spreading more or less evenly over an entire field. It frequently happens, however, that the disease is confined to a small area, as, for instance, an area 30 to 50 feet in diameter. In such cases it is extremely desirable to dig an ordinary ditch about 2 feet deep about this area, and at a distance of several feet from the visibly infected area. This ditch will usually suffice to prevent the further spread of the fungus, and it is an easy matter to control it in a small area.

General considerations.—In reviewing the foregoing paragraphs it will be observed that the various recommendations offered or suggestions made are all in the direction of good cultivation. Any method of culture or application of any material to the cane that will produce the most healthy and vigorous growth will serve best to keep the root fungus in check. This, together with removal of the diseased trash, has been found effective in reducing the loss by root fungus to a minimum. Attention to the removal of diseased material; good cultivation, and the rotation of crops, then, are the various matters to be considered in treatment of the root disease.

It is urged that all planters make a careful examination of their fields to ascertain as nearly as possible the loss by this disease. An actual count of the number of stools affected on various areas should be made. Consideration should be taken of those stools which are a total loss and those only partially diseased. It is pointed

out that in many apparently healthy stools there are often several stalks at least partially destroyed by this fungus. A loss of anything less than 10 per cent might be inconspicuous, and thus might not come to the attention of the planter without careful examination, while such a loss occurring in a number of stools would average up to a serious amount. It is believed that by attention to these details the planter may be able to overcome not only the disease where it is making a visible loss, but also be able to improve the entire stand of cane where the root fungus has been present in any quantity whatever.

PINEAPPLE DISEASE.

Planters frequently attribute the failure of their seed in sprouting to dry weather or to poor seed. While these are factors in the trouble, it must be recognized that there is also a distinct disease which results from fungus infection. Dry weather and poor seed are in themselves the cause of some direct loss, but more often they so weaken the seed that it is rendered more susceptible to attacks of the pineapple disease. It is also true that this disease can attack good seed growing under favorable conditions.

If seed that has failed to sprout is removed from the soil and examined it will often be found that the interior of the cane shows a black or a red and a black discoloration, which may be only at the ends or may extend entirely through the cuttings. The fungus that causes this trouble lives on the food material of the seed, and thus prevents it from growing into a healthy cane stalk. If the fungous infection has taken place at an early period, death of the cane results, but if the seed started germinating before the infection it is possible that roots may grow out, and the plant may thus be able to develop independently of the condition of the seed. The infection occurs through the cut ends or through cracks, and may take place both from the soil and from the air before the seed is planted. Seed cut for planting should never be allowed to lie about the plantation before treatment with a disinfectant. Disinfection of the seed and covering it with a fungicide will prevent the infection, thus almost entirely preventing the loss due to this disease.

The cause of this pineapple disease is a fungus, *Thielaviopsis ethacetica*, which is common in nearly all cane-growing countries, and has been found in nearly all parts of Porto Rico. The fungus consists of a fine thread-like growth or mycelium, which grows into the cane tissues. It is reproduced by many microscopic bodies, which in a mass appear black. If exposed to the air these tiny bodies or spores can be blown about by the wind, thus causing a wide distribution. The fungus may also be spread by infected seed being taken from one field to another. This fungus is so common that it is not safe to consider any field free from it. If in certain fields all of the cane seed grows up into a good stand without the loss of any seed, it may be assumed that that field is free, but if only disinfected seed was used, and for that reason the cane proved good, it is not safe to assume that the following year the field will be free from the disease and that treatment of the seed may be omitted.

A discussion of the best method of making up a mixture to disinfect the seed and of using it is given in following paragraphs: Bordeaux mixture is at present considered the best material and is usually sufficient. It has, however, sometimes been considered desirable to dip the ends of the seed in some heavier mixture than Bordeaux in order to better protect the seed from infection. Tar has been used for this purpose, but need only be applied in extreme cases. The tar is prepared for use by adding to every gallon of it a half pint of alcohol or of kerosene. The method of applying consists merely in covering about two inches of each end with this liquid. For this purpose the seed are tied together in a bundle and dipped into a shallow pan containing the liquid. No very practical means has as yet been devised for doing this on a large scale. For ordinary purpose, however, the treatment with Bordeaux mixture is considered sufficient.

BORDEAUX MIXTURE FOR TREATMENT OF SEED.

After careful selection of good cane seed for planting, treatment should be made with Bordeaux mixture. Even with the most careful selection there are likely to be on the external tissues of the seed some fungous spores which necessitate treatment to destroy them. And, moreover, if the solution is made up and applied properly it will provide a protective covering to the seed that will ward off attacks of the fungi

that are in the soil. By those planters who have used Bordeaux mixture it has been found that the loss by seeds failing to sprout has been reduced to a very small per cent. As this in some cases has been considerable and the use of the Bordeaux is very cheap, it is desirable to adopt it as a regular process in cane growing.

Bordeaux mixture consists of a mixture of copper sulphate, quicklime and water. The best proportions to use are 4 pounds of copper sulphate, 5 pounds of quicklime and 50 gallons of water. The copper sulphate is very slow in dissolving, so that it is desirable to attend to that, the day before making the mixture. An ordinary wooden bucket or tub may be taken and filled with a known amount of water. The copper sulphate should be suspended in a sack or netting of some kind just below the surface of the water. The reason for suspending the sulphate is that it dissolves more readily at the surface than at the bottom. As it is heavier than water it quickly sinks to the bottom and tends to concentrate there, thus retarding the solution of the crystals. If just one 50-gallon lot of the mixture is to be made it is sufficient to suspend the 4 pounds of the copper sulphate in a bucket of 3 gallons of water, although any larger known amount will do. After complete solution it is placed in a barrel and diluted to amount to 25 gallons when it is ready for mixing with the lime.

In Bordeaux mixture only fresh stone lime should be used. Just enough water should be added to the lime to slake it slowly. The stone rapidly crumbles to a powder on the addition of the water, and it can be readily stirred until it is diluted with sufficient water to be of heavy milky consistency. The amount of lime used and the amount of water added should be noted. If only the one 50-gallon lot is to be made the 5 pounds may be slaked and diluted to 25 gallons. On the other hand, if much of the lime is to be used, it will facilitate matters to slake a large amount and then that which is not used immediately may be kept in good condition if covered with water.

For making the 50-gallon mixture, the copper sulphate solution, consisting of 4 pounds of the sulphate in 25 gallons of water, and the lime milk, consisting of 5 pounds of lime in 25 gallons of water, are gradually brought together. The best method is to have a large barrel holding 50 gallons or more or a tank of similar capacity. Then two men, working each with a small wooden bucket of equal capacity, pour the two solutions together into the large barrel or tank. This is easily accomplished by holding the buckets close together as they are emptied of their contents.

When the mixing of the lime and sulphate is completed a test should be made as to the character of the results. There should not by any chance be an excess of the sulphate as it might injure the eyes of the seed. A small amount of potassium ferrocyanide—10 or 15 cents worth is sufficient—is obtained and a 10 per cent solution in water is made. One drop of this solution in the Bordeaux mixture will produce a red-brown color if the mixture is not good. If the mixture is good yellow-colored solution of potassium cyanide will disappear in the blue of the Bordeaux without changing its appearance. If the red-brown color has appeared more milk of lime should be added until the red fails to show.

Good commercial copper sulphate can be obtained for 8 or 9 cents a pound in 100 pounds lots, and quicklime is \$2.50 a barrel of about 150 pounds. These prices become much lower when the material is purchased in large quantities. As a result this treatment of the seed can be made at a cost much below the loss due to the failure of the seed to germinate.

In the treatment with the Bordeaux mixture the seed should be entirely immersed in the liquid and should be allowed to remain there for at least five minutes. This will be sufficient to kill all the fungous spores or mycelium on the surface of the seed. In order to handle the seed conveniently they should be placed in a basket or sack, the size of this depending on the amount of seed handled and the size of the barrel or tank containing the Bordeaux mixture. If only small quantities of seed are to be treated the 50-gallon barrel described in the foregoing paragraph will be sufficient to hold the liquid, and a basket of such size that it can be conveniently placed in the barrel will suffice to hold the seed. If, on the other hand, a large quantity of seed is to be treated, it is desirable to construct a large concrete tank. Suitable dimensions for this are as follows: Nine feet long, 5 feet wide, and 3 feet deep. Four feet from one end a partition should be made across the tank, and then this compartment should be divided in the middle so that there will be two small compartments each about 4 feet long, 2½ feet wide, and 3 feet deep. One of these small com-

partments can be used to hold the copper sulphate solution, and the other for the lime. Then in the large compartment, which is about 5 feet wide, 5 feet long, and 3 feet deep, there should be placed across the outside end a shelf 2 feet wide and almost even with the top of the tank. This shelf should be made of narrow boards, with space left between them. The copper sulphate and the lime are prepared in the small compartments at the end of the tank and then poured together, as already described into the large compartment. Into this compartment the basket containing the seed is allowed to stand for five minutes and then placed on the shelf to drain. The construction of the shelf is such as to allow the liquid to drain from the seed back into the tank, where it can be used over again. The basket or sacks may be of any convenient form or size. An ordinary one bushel or two bushel basket is often used for this purpose, as it can be conveniently lifted by one or two men into the tank and out again. If it is desired to dip a very large amount of cane at one time it is necessary to have large pieces of sacking, in which the seed are placed, and then the bundle is lifted by means of a small derrick into the tank and out again. Care must be taken that all of the seed is immersed and none is left standing above the liquid. After draining all of the superfluous liquid from the treated seed they are put out in a pile to dry before being planted.

It is recommended that every planter adopt this method of treatment of the seed. It is also recommended that each year a portion of the seed be left untreated. In this way a comparison of the untreated and the treated seed can be made, and it can be definitely ascertained whether to attribute the death of the seed to fungus disease or to drought or to other unfavorable conditions. It is not quite enough to be able to overcome difficulties. At times it is very desirable from a financial point of view to know exactly how they are overcome.

RIND DISEASE.

The rind disease is one of the most common and best known of all the sugar-cane diseases. Planters and investigators are, however, not at all agreed as to the amount of loss due to it. In Barbados some years ago it was said to cause very serious loss, while in other countries it has been claimed that this fungus said to cause this trouble was a harmless saprophyte. It is found in practically all cane countries, and is common in many parts of Porto Rico. It is so common that I believe it may be expected to occur anywhere the best care of the cane is not taken.

So far as Porto Rico is concerned, this disease is found seldom, if ever, on healthy, vigorous cane. On cane that has been injured or lying down, owing to being too heavy to stand, it frequently occurs on any part of the stalks. Particularly, however, on cane whose tops are diseased from the moth borer, or on cane which has stood too long and is suffering from the top rot, this fungus commonly appears on the upper joints. If left standing the cane becomes filled with the fungus from top to bottom; the stalk becomes dry, and the sugar content is rendered very low.

The black eruptions of this fungus on the surface of the cane are easily seen by the naked eye, and are so common as to be familiar to every planter. It must be remembered that cane left standing affected by this trouble soon becomes worthless and the fungus multiplies and is able to spread over a larger area. Infected stalks should either be destroyed by burning, or put through the mill and the fungus destroyed in that way.

It should also be noted that cane infected by this fungus does not make good seed, but on the contrary is worthless for such a purpose. It will usually fail to grow at all, or if it does start the resulting cane will be infected, and as such of little value.

The fungus causing this disease is known as *Melanconium sacchari*, or owing to another form of growth which it is said to have it is also called *Trichosphaeria sacchari*. There is much confusion among investigators as to the relation of rind fungus to the stem-rot fungus and to that causing the pineapple disease. For practical purposes, however, it will suffice if each one is considered a distinct disease and treated as such.

RED ROT OF THE STEM.

There is one serious cane disease whose effects are not fully appreciated by the cane grower, but the results of which are apparent in the grinding of the cane. This is the red rot of the stem, which has little visible external effect on the cane plant, but which greatly reduces the sugar content of the stalk.

The fungus causing the stem rot usually gains entrance to the cane through injuries, particularly those caused by the moth borer. After getting a foothold in the stalk the fungus grows through the tissues and causes a red discoloration and changes the sugar into useless organic compounds. The effect on the growing cane is not very apparent, and for that reason the planter can scarcely be expected to be aware of its presence. It is a good plan before cutting cane for grinding to sample the various fields by cutting stalks and examining for discolored or soured internal tissues. Those fields showing the most of this disease should be cut for grinding before the more healthy fields, as the longer cane infested with stem rot stands the greater will be the loss in sugar content. Overripe cane should in no case be allowed to stand, as it is particularly subject to these fungus attacks.

In selecting seed for planting all seed that shows reddening of the inner tissues should be discarded, as the presence of the fungus is likely to kill the seed or at least injure the eyes so that only a poor stand of cane will result.

The fungus causing this trouble is *Colletotrichum falcatum*, and in the case of dry and badly diseased cane the fructification may sometimes be found on the surface of the stalks or on the lower parts of the leaves. These fructifications appear as minute black spots, and under a hand lens can be seen to consist largely of black bristles. These tiny black spots must not be confounded with the black eruption of the rind disease, which may often be found accompanying them, but which are considerably larger.

Any means that will tend to reduce the number of stalk borers will also help to reduce the loss by the stem rot. Attention to destroying old cane on which there are fructifications of this fungus and cutting the cane before it has stood too long will also aid in reducing the total loss.

RED SPOT OF THE LEAF-SHEATH.

There occurs very commonly on the leaf-sheaths of cane bright red spots with black centers. These spots appear much brighter on the upper sheaths than on the lower, because they are surrounded by fresh green tissue. The spots eventually spread so as to kill the entire sheath. If the outer sheaths are removed it will be found that the spots become smaller as the center is approached. On the inner sheaths there are likely to be many small red spots instead of one of two large ones. If the disease has progressed to a great extent it reaches the very center or bud of the cane.

The amount of damage due to this disease is not known. Leaves affected by it die prematurely, and it must in consequence have some influence on the vitality of the plant. Undoubtedly dry weather would so weaken the plant that the effect of the fungus would be more than usually serious.

The fungus causing this disease is *Cercospora vaginæ*, which is found not only in the West Indies, but also in Java and India. It is common in practically all parts of Porto Rico. The mycelium of the fungus grows within the tissues of the leaf-sheaths, there drying out the plant juices. The first effect of the fungus is a disintegration of the juice and a consequent red discoloration of the tissues. Ultimately the fungus forms black fruiting bodies, which cause the dark discoloration of the center of the red spot.

So far as known at present it will not pay to strip the diseased leaves from the cane as the injury to the stalks would be very great. In the preparation of cuttings for planting, however, it is advisable to remove the infected leaf-sheaths and in that way the amount of fungus present will be considerably reduced. The wounds on the cutting caused by the stripping will be protected by the fungicide that is used in dipping all seed before planting, i. e., Bordeaux mixture.

RED ROT OF THE LEAF-SHEATHS.

This disease has been reported from Java and from Barbados, and very likely occurs in all cane-growing countries. It is very common in Porto Rico, having been found on all the estates which I have examined.

Symptoms of this disease are an orange red discoloration of the leaf-sheaths and the presence of some spherical bodies called sclerotia. These are about the size of a pin head and vary in color from white to yellow, pink to brown, according to their age. These sclerotia are firm bundle of mycelium, with a thick hard covering, and serve to enable the fungus to withstand unfavorable conditions. In extreme drought the ordinary growing mycelium would dry up, or if insufficient food material was available the same result would take place. The sclerotia, however, can exist for a long period, and when more favorable conditions arise can grow out into the ordinary vegetative condition. Fructifications by which this fungus multiplies itself are not known, although in a way the sclerotia serve the same purpose.

This disease usually affects only the leaf-sheath, though indirectly it will affect the leaf-blade also. The effect on the plant is to reduce its vitality, sometimes to such an extent that it becomes dwarfed and has little value as cane. It is rare to find large areas of cane seriously injured by this fungus, but it is quite common to find individual stools which have failed to grow properly on account of this. Not only do single stools suffer, but also individual stalks of apparently healthy stools. For this reason it is difficult to estimate the entire loss.

Whenever the disease becomes serious it is desirable to pull up the dwarfed stools and to strip off the infected leaves from more healthy stools. All infected material should be destroyed by burning.

DRY ROT OF THE CANE STEM.

One cause of this disease is a conspicuous fungus called *Schizophyllum commune*, which appears as a more or less fan-shaped, lobed outgrowth from the side of the stem. The fungus is gray in color and has a slightly woolly surface. Often these fructifications are very numerous on a single stem. The vegetative part or mycelium grows within the cane stalk, causing it to shrivel and dry up. The effect of the fungus is not only to harden the cane, but also to lower the sugar content.

It is not commonly believed by planters that this fungus is anything more than a harmless saprophyte, but I have found it very abundant on a small area of standing cane on the south side of Porto Rico, and in a more scattered area on the north side. So far as could be seen there was nothing else to which one could attribute the disease of the cane, and it was very noticeable that surrounding uninfected stalks were in a healthy condition. It is true that this same fungus is very common in all parts of the island on dead cane or stubble which has been left lying about the field. This, however, is no indication that the fungus may not become an active parasite under certain conditions. This being the case care should be taken that infected stubble or trash should not be left about the field, but should be gathered and destroyed by burning. This fungus is not by any means confined to Porto Rico, but is found also other parts of the West Indies and Brazil.

In addition to the dry rot of the cane caused by *Schizophyllum commune* there is a similar disease caused by a species of *Hypocraea*, possibly *Hypocraea sacchari*, described by Went as occurring in Java.

This fungus appears as small groups of tiny spherical rust-colored bodies, which break through the rind of the cane usually near the joints. These bodies are the fructifications which serve to reproduce the fungus. The vegetative part grows within the stem and there dries out the tissues and reduces the sugar content.

Fortunately the fungus so far has been found only in the vicinity of Rio Piedras, Carolina, Loiza, and Fajardo. It attacks only weak or injured cane, and consequently any methods used to avoid injury or to increase the vigor of the cane will serve to overcome the attacks of this fungus.

STEM ROT OF THE CANE.

Quite different from the stem rot caused by *Collectotrichum* and the dry rots caused by *Schizophyllum* and by *Hypocraea* is still another rot produced by a species of *Fusarium*. In this case the cane stalks affected are diseased by some other fungus or have been injured so that the normal processes of growth in the cane have been stopped. The fungus grows within the stalks and protrudes through cracks, eyes

or through the adventitious roots for fructifications. On the surface of the cane the fungus appears as small pink clumps, and the longer the diseased stalk is allowed to remain in the field the more the sugar content will be reduced and the wider will be the spread of infection, it is desirable either to grind such infected cane early or to destroy it by burning. Fortunately the disease is not widespread, but occurs only in isolated positions in which the cane is poorly cared for.

LEAF SPOTS OF THE SUGAR CANE.

There are several kinds of spots on the leaves found in Porto Rico, and at least two of them correspond in appearance with those described from other countries. This, however, has not been proved by actual identification of the fungi. These two diseases are the Ring-spot, caused by *Leptosphaeria sacchari*, and the eye spot, caused by *Cercospora sacchari*. As these diseases are very similar it is sufficient for the present to consider them as one.

The diseases appear as small, more or less rounded, reddish spots, with tiny black fructifications in the middle. The injury to the cane is caused by the loss of green leaf surface, which is essential to the proper vigor of the plant and to the manufacture of a sugar content. There is no direct method of treatment, but it has been found that certain varieties of cane are less liable to these diseases than others. Cristalina, for example, is much freer from these fungi than the ordinary white cane of T77. Any cane exposed to a strong wind or suffering from a severe drought is more subject to these diseases than when growing in more favorable conditions.

TOP ROT.

Top rot is a designation given to cane in which the top is rotted from any cause whatever. This disease, if it may be called such, usually occurs in borer infested cane or in cane which is overripe.

The actual cause of this top rot has not been determined. The fact that the moth borer often accompanies this diseased condition lends color to the supposition that the borer is the cause of the rot. On the other hand, in the case of large stands of cane that are overripe this same rotted condition of the top is evident even in the absence of the moth borer. It has been observed, however, that some varieties of cane are much more subject to this overripe condition than others. The white cane particularly "goes bad" or rots back very soon after maturity, particularly in dry weather, while the cristalina cane continues green long after maturity.

The probable facts of the case are that the rot is actually caused by bacterial organisms, and that these organisms are introduced into the cane tissues by insects, moth borers and other varieties, and that any condition which tends to weaken the vigor of the cane renders it more susceptible to the action of these bacterial organisms.

The evil effect of the top rot is threefold. It stops further growth of the cane and causes the eyes to bud out and often produces long shoots, much to the detriment of the sugar content. It renders the top unfit for use, and this deprives the planter of his best seed. And, further, it so decays the top that in the majority of cases the rind disease and the stem rot gains a foothold, and when the cane is allowed to stand these diseases diminish the sugar content to a great extent.

The obvious remedies for this disease are the control of the moth borer as directed by the Station Entomologist, and the early grinding of all affected cane.

It has been mentioned here that the white cane is subject to the top rot more than the other cane varieties. The same is true of its susceptibility to other diseases. At the same time it is recognized that this cane is one of the best when grown under good conditions. Judging from the history of this cane in Porto Rico and other of the West Indian islands it has degenerated in the hardy characters, such as it has been said to have had and such as is found in other canes at present. It seems very possible that by selection of cane seed and breeding of different strains the original hardy characters may be obtained, together with the present good sucrose content and good milling qualities.

CHLOROSIS.

On the south side of the island there has been observed a disease of the cane due entirely to the soil. On several plantations small areas of the cane was bleached out almost entirely white, a condition occurring both in the young plants and in the old. Absolutely no fungi or insects appear to have any relation to the trouble. It always occurs where there is an excess of lime, such as when the limestone rock is near or at the surface. Such soil has a poisoning effect on the cane and prevents the proper formation of the green colored bodies in the leaves which, as has already been described, are essential to the proper life of the plant. At present no definite recommendation can be made for an improvement of the soil condition. It has, however, been shown by Mr. C. T. Murphy, of Guánica Central, that Barbados 1753 appears to be much more resistant to the lime than other varieties, so that it is well to try that cane under such circumstances.

In examining these various diseases of sugar cane there have appeared certain relationships and conditions which require considerable study to understand. Many of them will have to be worked out by a series of experiments and will require considerable time for solution. It seems desirable to mention in conclusion some of the most important problems. It is not possible at this time to give a plan of work for the pathologist, as certain lines of work will take longer for completion than anticipated, and other subjects will appear in the course of time that will need early consideration.

In the matter of the root disease there should be ascertained the effect of the root fungus on cane free from other diseases and from insect enemies. The relation of the various fungi associated with this malady should be fully worked out. Experiments should be made to ascertain if good cultivation is in all cases sufficient to overcome the effects of the root fungus. It has been pointed out by other workers that in some cases, even with the use of much fertilizer, with the best cultivation and with good moisture conditions, it is impossible to get good crops. This matter should be further studied in relation to the root fungus of the cane.

On the subject of the pineapple disease it should be ascertained if there is not a disinfectant which will adhere to the cane seed better than Bordeaux mixture. Bordeaux is an excellent disinfectant, but does not always adhere well to the seed in the soil. Experiments should also be made with the use of Bordeaux alone and in comparison with the use of Bordeaux and an application of tar to the cut ends of the seed. The relation between bad top seed and the pineapple disease is also important and not at all clear.

As to the stem rot it should be determined whether the fungus can affect healthy cane or not, and its relation to the top rot should also be ascertained.

The red spot of the leaf sheath must be studied to ascertain the amount of injury caused by leaving the affected sheaths on the seed in planting.

There are numerous other questions of more or less importance that must be worked out and they will be taken up as time permits. Altogether it has been found from examination of plantations in different parts of the island that many of the diseases occurring in other cane countries also occur in Porto Rico, and it is believed that a thorough understanding of these subjects will be of considerable assistance to the planters in obtaining better results from their cane growing.

J. R. JOHNSON.
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Río Piedras, Abril 30, 1911.

Sugar Growers' Association of Porto Rico.

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